UNIVERSITY OF NOTTINGHAM

REPORT OF THE SCHOOL OF AGRICULTURE

1959

COMMONWEALTH MYCOLOGICAL INSTITUTE
1 MAY 1960

UNIVERSITY OF NOTTINGHAM SCHOOL OF AGRICULTURE

UNIVERSITY OF NOTTINGHAM

REPORT OF THE SCHOOL OF AGRICULTURE

1959

SUTTON BONINGTON
LOUGHBOROUGH
LEICESTERSHIRE
1960

CONTENTS

		PAGE
Introduction		5
University Officers and School of Agriculture Advisory Committee		9
Staff		11
Work of the School of Agriculture		17
Articles:		
The Agricultural Sciences Building	*E. G. Hallsworth* ...	29
Sixth University of Nottingham Easter School in Agricultural Science	*J. D. Ivins* ...	37
Grassland values on the farm	*J. D. Ivins* ...	39
The growth of the potato plant	*M. N. Borah & F. L. Milthorpe* ...	41
The propagation of plants by leaf cuttings	*M. E. Marston* ...	45
The role of boron in plant nutrition	*W. J. Whittington* ...	51
Studies on common scab of potato	*B. G. Lewis & T. H. Nicolson* ...	53
Crop variety testing ...	*J. C. Llewelyn* ...	57
Foetal development in pigs ...	*J. T. Morgan & F. R. Green* ...	62
Factors affecting fertility in female sheep	*D. M. Allen & G. E. Lamming* ...	64
The response to fertiliser application of some East Midlands fattening pastures	*R. B. Jones & K. E. Hocknell* ...	70
The weather in 1959 ...	*T. Webster* ...	76
Publications from the School of Agriculture—1959		80
Lectures and Papers—1959		84
Titles of theses admitted for higher decrees in the Faculty of Agriculture and Horticulture—1959		89
Publications for Sale		90

INTRODUCTION

THE UNIVERSITY OF NOTTINGHAM SCHOOL OF AGRICULTURE

THE School of Agriculture in its present form came into being in 1947 with the transfer to the University College of Nottingham of the buildings and land at Sutton Bonington held by the former Midland Agricultural College. This College had its origin in the Department of Agriculture (founded in 1893) of the University College of Nottingham and in the Midland Dairy Institute (founded in 1895). These were combined in 1900 to form the independent Midland Agricultural and Dairy Institute, whose title was changed in 1906 to that of the Midland Agricultural College. For the first 30 years of its existence the principal function of the College remained the provision of certificate and diploma courses in Agriculture, Dairying and Poultry Husbandry. Collaboration between the Midland Agricultural College and the University College of Nottingham led in 1943 to the establishment of a Faculty of Agriculture and Horticulture and was followed four years later by the transfer of the College to the University, which received its Charter in 1948.

The School of Agriculture, consisting of the four University Departments of Agriculture, Agricultural Sciences, Horticulture and Agricultural Economics, is situated at Sutton Bonington, 10 miles south of the City of Nottingham, and lies between 100 and 250 feet above sea level in gently undulating country adjacent to the valley of the River Soar. The estate extends to about 600 acres, of which 300 are arable. Two farms are operated, one for demonstration and one for experimental purposes; the remainder of the land being occupied by the Department of Horticulture Demonstration Unit, ornamental and sports grounds and buildings. The buildings comprise: a central block in which are located lecture rooms, a library, common rooms, laboratories for the Agricultural Microbiology section and administrative offices; Halls of Residence and a Refectory; a Dairy which is one of the largest in the country used for teaching purposes; two large houses—" The Elms," converted for the use of the Agricultural Zoology section, and " St. Michael's," occupied by the Department of Agricultural Economics; and a new Agricultural Sciences building.

This last building, completed in 1959, accommodates the Agricultural Botany and Agricultural Chemistry sections of the Department of Agricultural Sciences and the Animal Physiology and Crop Husbandry sections of the Department of Agriculture. Facilities are provided for postgraduate and honours students in the above sections and for labora-

tory teaching in all subjects, except Microbiology, of the B.Sc. degree course. The building is equipped with service facilities for research, including cold rooms, constant temperature rooms, plant growth rooms, a small-animal house, a radio-isotope laboratory, preparation rooms, a hydrology laboratory, spectrographic and X-ray analysis laboratories, a photographic studio and a workshop. A Field Demonstration Unit comprising, *inter alia*, a grass garden, nutrition plots and lysimeters is being developed adjacent to the laboratories, and nearby are located experimental glasshouses, a number of which are insect-proof for entomological work. The School maintains an " agro-met " meteorological station and also keeps records of incoming solar radiation.

The Department of Agriculture consists of three sections—Crop Husbandry, Animal Husbandry and Animal Physiology, each with differing requirements for research and teaching. An Experimental Farm of some 160 acres provides facilities for research. These include a slaughterhouse and cold room; rooms for metabolism and digestibility studies with cattle, sheep, pigs and poultry; rooms for the use of radioactive isotopes; and a field laboratory. Accommodation, modified to permit individual or group feeding depending on the nature of the investigation, is available for pigs and broiler chickens and for a dairy herd of identical twins. In addition to the land required for research in crop and grassland husbandry, facilities are provided on the Experimental Farm for the regional trials of the National Institute of Agricultural Botany and for an extensive series of potato variety demonstration plots for the Ministry of Agriculture, Fisheries and Food. Some 350 acres based on Manor Farm, Kingston, is run as a commercial farm, with a separate labour force and equipment, and is used for teaching farm management and crop and animal production. A Demonstration Hall is available for teaching Farm Mechanisation and there is a fully equipped Engineering workshop for the maintenance of machinery.

In the Department of Horticulture there are facilities for research on various aspects of the effects of weather on the growth and yield of plants. These include the largest installation of lysimeters in the United Kingdom for the detailed study of soil/plant/water relations allowing the measurement of the daily rate at which water is used by plants, and equipment for subjecting plants in large numbers to different definable and reproducible water-regimes. Eight growth rooms, some of unusually large size, are available for investigations into the responses of plants to light and temperature. These are used for work in which tropical as well as temperate crops are grown all through the year under controlled environmental conditions. For teaching purposes the Department has a Demonstration Unit that includes about one acre of heated and unheated

glasshouses, an orchard of top and soft fruits, and a collection of ornamental species illustrating the wide range of plants used in decorative horticulture.

The Department of Agricultural Economics is a part of the Provincial Agricultural Economics Service for England and Wales and is responsible to the Ministry of Agriculture, Fisheries and Food for the supply of economic data about agriculture in the East Midlands. It is also responsible for advisory and extension work in farm management throughout the East Midlands Province.

The objectives of the School are twofold: to enlarge the stock of knowledge relating to Agriculture in its widest sense, and to disseminate it by means of undergraduate and postgraduate courses. The University of Nottingham maintains at the School courses of instruction for the degree of B.Sc. and candidates admitted to such courses may qualify for honours degrees in Agriculture, Agricultural Botany, Agricultural Chemistry, Agricultural Microbiology, Agricultural Zoology or Horticulture, or for pass degrees in Agriculture, Dairying or Horticulture. A course is also given leading to a diploma in Dairying. Enrolment for the current year included 134 students for first degree courses, 33 students for the diploma course and, excluding Demonstrators and Research Assistants, there are 26 post graduate students.

Apart from the Department of Agricultural Economics, extension work in agriculture is not a function of the School, although some is effected through visits of Young Farmers' Clubs, parties of farmers and other visitors to the experimental and demonstration fields and to the laboratories, and by lectures given by members of the staff to farmers' and growers' organisations and other bodies. During the period under review members of staff have continued to co-operate with the British Broadcasting Corporation in providing programme material for Sound and Television services.

The scientific work of the School centres around the study of the principles of crop and animal husbandry, and of the problems which may be associated with them. Expressed in more precise terms the aim is to conduct researches on soil, plant and animal problems relating to agriculture and horticulture and on the insect pests which affect production. Certain aspects of the work in progress, which has reached a stage suitable for review, are described in a later part of this report.

This research work is mainly financed from general University funds, but in recent years investigations have been aided by grants from other organisations to whom grateful acknowledgement is made.

During 1959 the Department of Horticulture continued to receive support from the Agricultural Research Council to the extent of £3,390 for the development of specific research work. £1,500 was donated by Whiffen and Sons and Fisons for the continuation of the study of plant responses to weather and £1,174 was received from the Royal Society.

Generous support towards the prosecution of experimental work has been received by the Department of Agriculture in the form of grants, gifts and assistance from British Drug Houses, Squibb and Sons, Pfizers, J. Sainsbury, T. Walls and Sons, British Oil and Cake Mills, Fisons, Midland Livestock Services and Boots. Studies on the effect of steroid hormones on the growth of animals have been developed through the generosity of the Leverhulme Trust Fund, which, during the period 1957-60 inclusive, has financed a senior and a junior fellowship and the expenses involved in this work. A further grant of £2,000 has been received from an anonymous donor to develop experimental facilities for work with poultry and pigs and the Pig Industry Development Authority has made a grant of £1,750 per annum for three years for studies on pig nutrition. The Agricultural Research Council are supporting investigations on potatoes and in addition have made a joint grant of £1,072 to the Departments of Agriculture and Agricultural Sciences for research work on poultry nutrition. Gratitude is also expressed to the numerous farmers in the East Midlands who have kindly given facilities for experimental work with livestock.

The final instalment of the grant of £3,000 from the Ministry of Agriculture, Fisheries and Food for the study of farm buildings was made in 1959 to the Department of Agricultural Economics, which also received a grant of £1,000 from Fisons to continue the investigation into the implications of the intensification of grassland production for beef cattle.

The Department of Agricultural Sciences has received a further contribution of £500 from the Agricultural Research Council for an investigation on sprout development of potatoes, £500 from Borax Consolidated for studies on the role of boron in root growth and £900 from Genatosan for work on the amino-acid requirements of farm animals. The Fellowship donated by the African Pyrethrum Board for insecticidal studies has been continued, and work on the biochemistry of the legumes has been supported by the Nuffield Foundation with a further instalment of the three-year grant of £4,450 made in 1958. Gifts and assistance to the Department of Agricultural Sciences from Fisons, British Drug Houses and the Midland Counties Dairies are also gratefully acknowledged.

THE UNIVERSITY OF NOTTINGHAM

Chancellor:
His Grace the Duke of Portland, K.G., LL.D.

Vice-Chancellor:
Bertrand Leslie Hallward, D.L., M.A.

Deputy Vice-Chancellor:
Professor Harry Raymond Pitt, B.A., Ph.D., F.R.S.

Dean of the Faculty of Agriculture and Horticulture:
Professor Ernest Gordon Hallsworth, B.Sc., Ph.D.

Registrar:
Alfred Plumb, M.A.

Secretary to the School of Agriculture:
Harry Harris, B.Sc. (Econ.), LL.B.

SCHOOL OF AGRICULTURE ADVISORY COMMITTEE

Alderman Sir Francis Hill, C.B.E., M.A., LL.M., Litt.D.
Mr. B. L. Hallward, D.L., M.A.
Mr. G. D. Bailey, J.P.
Professor E. J. W. Barrington, M.A., D.Sc.
Professor L. F. Bates, Ph.D., D.Sc., F.R.S.
Mr. W. G. Briggs, M.A. (Chairman)
Mr. H. Burtt
Mr. R. M. Chambers, B.Sc., B.Agr.
Professor C. G. C. Chesters, M.Sc., Ph.D.
Alderman H. Coltman, O.B.E., M.A., J.P.
Alderman Sir Weston Cracroft-Amcotts, M.C., D.L., J.P.
Councillor A. W. Dexter
Mr. N. E. Elliott
Alderman F. A. Gent, B.E.M.

Mr. W. S. Gibson, B.Sc.

Mr. J. C. Gifford, J.P.

Professor E. G. Hallsworth, B.Sc., Ph.D., A.R.I.C.

Sir John Hammond, C.B.E., M.A., D.Sc., F.R.S.

Mr. J. F. D. Hargreaves

Mr. C. L. Hempsall

Mr. C. E. Horton, C.B.E., M.A.

Professor J. P. Hudson, M.B.E., G.M., M.Sc., Ph.D., N.D.H.

Professor J. D. Ivins, M.Sc., Ph.D.

Alderman F. J. Jenkinson, O.B.E., J.P.

Mr. P. Lyth, B.Sc.

Mr. P. S. Marsden, M.C., M.A.

Professor F. L. Milthorpe, M.Sc. Agr., Ph.D., D.I.C.

Mr. P. A. Missen, M.A., Dip. Agric.

Alderman A. D. Potter, O.B.E.

Mr. J. W. Rowland, N.D.A., N.D.P.

Mr. B. Savage

Mr. E. F. R. Stearn, M.A., M.Sc.

Alderman G. E. Taylor, C.B.E., M.A., J.P.

Mr. J. B. Thomas

Alderman A. Thompson

THE UNIVERSITY OF NOTTINGHAM
SCHOOL OF AGRICULTURE

STAFF

DEPARTMENT OF AGRICULTURAL SCIENCES

Professor of Agricultural Chemistry and Head of Department:	E. G. Hallsworth, B.Sc., Ph.D. (Leeds), A.R.I.C.
Agricultural Chemistry:	
Lecturers:	
Soil Chemistry	D. V. Crawford, M.A., B.Sc. (Oxford)
Bio-Chemistry	D. Lewis, M.A. (Cambridge), M.Sc. (Wales), Ph.D. (Sheffield)
Dairy Chemistry	E. R. Ling, M.Sc. (London), Ph.D. (Nottingham), A.R.C.S., F.R.I.C.
Assistant Lecturers:	
Bio-Chemistry	G. Norton, B.Sc., Ph.D. (Nottingham)
Soil Physics	[1] E. A. N. Greenwood, B.Agr.Sc., (Melbourne), Ph.D. (Nottingham), D.D.A.
	I. R. Cowan, M.Sc. (London)
Nuffield Research Fellow:	I. H. Rorison, M.A., D.Phil. (Oxford)
Demonstrator:	[2] A. L. Lakin, B.Sc. (Reading)
Research Assistants:	P. E. Cansfield, B.Sc. (Wales)
	[3] G. H. Smith, B.A. (Cambridge)
Agricultural Botany:	
Professor:	F. L. Milthorpe, M.Sc. Agr. (Sydney), Ph.D. (London), D.I.C.
Lecturers:	
Agricultural Botany	K. W. Dent, B.Sc., Ph.D. (Birmingham).
	Miriam M. Edwards, M.Sc., Ph.D. (Manchester)

[1] Resigned September, 1959.

[2] Resigned March, 1959.

[3] Financed by Messrs. Genatosan.

Plant Pathology	T. H. Nicolson, B.Sc. (Agric.) (Aberdeen), Ph.D. (Nottingham)
Genetics	W. J. Whittington, B.Sc. (Wales), Ph.D. (Nottingham)
Demonstrator:	B. G. Lewis, B.Sc. (Bristol)
Research Assistants:	[4] Elizabeth M. Sadler, B.A. (Oxford).
	[5] C. R. Slack, B.Sc. (Nottingham)

Agricultural Microbiology:

Reader:	M. Woodbine, M.Sc., Ph.D. (Manchester), F.R.I.C.
Lecturer:	A. Seaman, B.Sc. (London), Ph.D. (Nottingham)
Demonstrator:	Kathleen N. Smith, B.Sc. (Edinburgh), M.Sc. (Nottingham).

Agricultural Zoology:

Lecturers:	P. W. E. Murphy, B.Agric.Sc. (N.U.I.), D.Phil. (Oxford)
	J. Y. Ritchie, B.Sc. (Agric.) (Glasgow)
African Pyrethrum Research Fellow:	W. N. Yule, B.Sc. (Glasgow)
Demonstrator:	I. V. Herbert, B.Sc. (Nottingham), M.S. (Iowa)

Dairying:

Lecturers:	R. Scott, B.Sc. (Agric.) (Nottingham), N.D.A., N.D.D.
	M. Stein, J.U. Dr. (Prague), B.Sc., Ph.D. (Leeds)
Departmental Assistants:	Maud Arnot, N.D.A., S.D.A., S.D.D.
	Rosemary J. Prince, B.Sc. (Reading)

[4] Financed by the Agricultural Research Council.

[5] Financed by Borax Consolidated Ltd.

DEPARTMENT OF AGRICULTURE

Professor of Agriculture and Head of Department:	J. D. Ivins, B.Sc. (Reading), M.Sc. (Agric.), Ph.D. (Nottingham)
Reader in Animal Physiology:	G. E. Lamming, B.Sc. (London), M.S., Ph.D. (Illinois), N.D.A. (Hons.)
Lecturers:	
Agricultural Engineering	J. Chatterton, D.F.C., B.Sc. (London), M.Sc. (Nottingham)
Animal Husbandry	J. T. Morgan, M.Sc. (Wales), Ph.D. (Nottingham), A.R.I.C.
	F. R. Green, B.A., Dip. Agric. (Cambridge), Ph.D. (Nottingham)
Crop Husbandry	P. M. Bremner, B.Sc. (Edinburgh), M.S. (Cornell), Dip. Agric. (Cambridge).
Part-time Lecturers:	
Farm Accountancy	H. Harris, B.Sc. (Econ.), LL.B. (London), D.P.A., F.C.C.S.
Farm Buildings	P. J. M. Aston, M.A. (Cambridge), A.R.I.C.S., Q.A.L.A.S.
Honorary Lecturers:	
Veterinary Hygiene	J. C. Buxton, B.Sc., Ph.D. (Nottingham), M.R.C.V.S.
	Connie M. Ford, M.R.C.V.S.
Leverhulme Research Fellows:	
Senior	A. A. Wright, M.A. (Cambridge), Ph.D. (London)
Junior	W. R. Shorthose, B.Sc. (Nottingham)
Fison Research Fellow:	R. D. Harkess, B.Sc. (Edinburgh), M.S. (Cornell).
Demonstrators:	R. A. Costain, B.Sc. (Nottingham)
	R. L. Hall, B.Sc. (Nottingham).
Research Assistants:	[6] R. W. Radley, B.Sc. (Nottingham)
	[7] D. W. Robinson, B.Sc. (Nottingham).

[6] Financed by the Agricultural Research Council.

[7] Financed by the Pig Industry Development Authority.

Farm Manager:	A. C. Thompson
Superintendent of Potato Trials:	Nora McDermott, M.B.E., M.Sc. (Agric.) (Nottingham)
National Institute of Agricultural Botany Regional Potato Certification Officer:	T. Webster, B.Sc. (Agric.) (Glasgow), M.Sc. (Nottingham), Dip. Agric. Science (Wales), N.D.A.
National Institute of Agricultural Botany Regional Trials Officer:	J. C. Llewelyn, B.Sc. (Wales), S.D.A. (Hons.).

DEPARTMENT OF HORTICULTURE

Professor of Horticulture and Head of Department:	J. P. Hudson, M.B.E., G.M., B.Sc. (Hort.), M.Sc. (London), Ph.D. (Nottingham), N.D.H.
Lecturers:	Margaret E. Marston, B.Sc. (London), M.Sc. (Hort.), Ph.D. (Nottingham), N.D.H.
	W. Heydecker, B.Sc. (Hort.) (Reading), M.Sc., Ph.D. (Nottingham), N.D.H. (Hons.)
	Winifred M. Dullforce, M.Sc. (Nottingham), N.D.H.
Whiffen and Sons Research Fellowship:	[8] J. Dancer, B.Sc. (Hort.), Ph.D. (London)
	D. V. Clay, B.Sc. (London).
Demonstrator:	W. R. Buckley, M.Sc. (London)
Research Assistants:[9]	Josephine M. Cook, B.Sc. (Nottingham)
	J. G. Davison, B.Sc. (Nottingham)

DEPARTMENT OF AGRICULTURAL ECONOMICS

Senior Lecturer and Provincial Agricultural Economist:	[10]K. Rasmussen, Cand. polit. (Copenhagen).
Senior Agricultural Economists:	R. B. Jones, M.Sc. (Wales)
	E. Mejer, M.Sc. (Vilno), M.Sc. (Agric.) (Nottingham)
	W. S. Senior, B.Sc. (Agric.) (Leeds)

[8] Resigned December, 1959.
[9] Financed by the Agricultural Research Council.
[10] Resigned July, 1959.

Agricultural Economists:	R. O. Wood, M.Sc. (London)
	K. A. Ingersent, B.Sc. (Aberdeen), M.S. (Minnesota)
	T. K. Warley, B.Sc. (Hort.), M.Sc. (Nottingham)
Assistant Agricultural Economists:	[11]D. P. Baron, B.A. (Econ.) (Manchester)
	H. G. Evans, B.Sc. (Wales)
	G. E. Jones, B.A. (Manchester)
	Margaret M. Sandilands, B.A. (London)
	T. W. D. Theophilus, B.Sc. (Wales)
Research Assistant:	K. E. Hocknell, B.Sc. (Nottingham)

ADMINISTRATION

Secretary to the School of Agriculture:	H. Harris, B.Sc. (Econ.), LL.B. (London), D.P.A., F.C.C.S.
Senior Tutor:	J. T. Morgan, M.Sc. (Wales), Ph.D. (Nottingham), A.R.I.C.
Librarian:	Nancy W. Rhodes, B.A. (London), A.L.A.
Administrative Assistant:	Muriel I. Wood
Surveyor:	C. N. Thompson, F.E.C.W., A.I.C.W.
Chief Technician:	F. C. Treeby

[11] Resigned January, 1959.

FULL-TIME POST GRADUATE STUDENTS

	Subject	Degree
I. A. Babiker, B.Sc. (Agric.) (London), Dip. Agric. (Khartoum)	*Agricultural Chemistry*	M.Sc.
R. L. Burt, B.Sc. (Reading)	*Agricultural Botany*	Ph.D.
D. R. Cullimore, B.Sc. (Nottingham)	*Agricultural Microbiology*	M.Sc.
B. N. K. Davis, B.Sc. (Aberdeen)	*Agricultural Zoology*	Ph.D.
C. P. Freeman, B.Sc. (Birmingham)	*Agricultural Chemistry*	Ph.D.
M. P. Grant, B.Sc. (Nottingham)	*Animal Physiology*	Ph.D.
D. W. R. Headford, B.Sc. (Nottingham)	*Agricultural Botany*	Ph.D.
R. B. Heap, B.Sc. (Nottingham)	*Animal Physiology*	Ph.D.
J. M. Hopkinson, B.Sc. (Nottingham)	*Agricultural Botany*	Ph.D.
H. Jackson, B.Sc. (Nottingham)	*Agricultural Microbiology*	M.Sc.
P. C. Jain, B.Sc. (Agric.) (Delhi)	*Horticulture*	M.Sc.
A. I. Kheiralla, B.Sc. (Nottingham)	*Agricultural Botany*	M.Sc.
F. Nicholl, M.B., Ch.B. (Leeds), B.Sc. (Hort.) (London)	*Horticulture*	M.Sc.
M. M. Saad, B.Sc. (Agric.), M.Sc. Cairo)	*Agricultural Economics*	Ph.D.
J. A. T. Saul, B.Sc. (London)	*Agricultural Chemistry*	Ph.D.
A. G. Schaffer, M.Sc. (London)	*Agricultural Chemistry*	Ph.D.
M. A. Taha, B.Sc. (Agric.) (London), Dip. Agric. (Khartoum)	*Crop Husbandry*	Ph.D.
N. White, B.Sc. (Durham)	*Animal Physiology*	M.Sc.
S. B. Wilson, B.Sc. (Nottingham)	*Agricultural Chemistry*	Ph.D.
T. G. Wood, B.Sc. (Durham)	*Agricultural Zoology*	Ph.D.
M. G. Yates, B.Sc. (Wales)	*Agricultural Chemistry*	Ph.D.

PART-TIME POST GRADUATE STUDENTS

D. Gunary, B.Sc. (Nottingham)	*Agricultural Chemistry*	Ph.D.
D. G. A. Gutteridge, M.Sc. (Nottingham)	*Animal Husbandry*	Ph.D.
P. J. Harris, B.Sc. (Nottingham)	*Agricultural Microbiology*	M.Sc.
A. Loughton, B.Sc. (Nottingham)	*Horticulture*	M.Sc.

THE WORK OF THE SCHOOL OF AGRICULTURE

The problems under investigation fall into several groups which can be enumerated as :

(a) Soil topics—investigations into the nature and distribution of soils and of the processes responsible for their formation.

(b) Factors affecting plant growth—the weather, water relations, mineral nutrition, cultural practices, weed competition, etc.

(c) Factors affecting animal growth and reproduction—nutrition, the level and effect of different hormones.

(d) Problems connected with the effect of insects and other invertebrates.

(e) Microbiological problems affecting either plant or animal health, or concerning the utilization of agricultural products.

(f) Farm management and returns in relation to the national economy.

The investigations in progress in each of the fields are reported briefly below, and more complete accounts of certain topics are given later.

Soil Studies

Studies on the mechanism of podzolization have continued. During the year under review attention has mainly been directed to factors affecting the deposition of iron and organic matter. The extent of such deposition from incubated podzol extracts on samples from the B and C horizons has been measured. A physicochemical sorption appears to be the initial process and the extent of this has been examined in relation to the following soil properties : anion and cation exchange capacities, organic matter, pH, and clay and iron contents. The soils from B_H-horizons and from B_{Fe}- and C-horizons behave differently and it has not yet been possible to find any general expression which relates sorption to soil properties and is applicable to both groups. Thus the uptake by the first group of soils shows a weak negative correlation with anion exchange capacity, but the second group shows a strong positive correlation. Apart from this physical process, definite evidence has been found that micro-organisms contribute to the maintenance of the sorptive process, and visible pan-formation due to the action of organisms has been obtained.

Work has been commenced on the characterization of soil profiles from both the Millstone Grit and the Carboniferous limestone soils of the southern end of the Pennines. Preliminary results show little evidence of podzolization on the gritstones; its absence may be associated with the high clay contents that have been found.

A survey of the soils of the University farms has now been completed and a map is being prepared for publication.

Factors affecting plant growth

Studies of the mineral nutrition of legumes in the Agricultural Chemistry section have been continued. The effect of aluminium in restricting root growth has been investigated further by respiration studies using isolated root tips, but no marked effect has so far been observed. The cation exchange capacity of roots of several species has been measured but, with the small samples of material available, present techniques are not sufficiently accurate to allow differentiation between these.

Work on the effect of copper has been continued and a change in the amino-acid pattern in subterranean clover with change in the level of copper supply has been demonstrated. The effect of copper on nodulation and growth appears to be affected by the light energy received. Using the plant growth rooms it has been found that at very low and at high levels of light energy the effect of variations in copper level previously demonstrated cannot be obtained. This rather complex interrelationship is being explored further.

An attempt has been made to investigate the possibility that cobalt, which affects the formation of haemoglobin in animals, might also play a role in the growth of the legumes. These when nodulated with an effective N-fixing strain of rhizobia also contain haemoglobin, the quantity of which has been shown elsewhere to vary with the amount of nitrogen fixed. Preliminary results are most promising and with subterranean clover a significant increase in N-fixation has been shown to occur when cobalt is added to the nutrient solution used at the rate of 0.0006 and 0.006 p.p.m. Higher levels reduce growth at least under the conditions explored so far. These same levels of cobalt increased the number of leaves formed during the early period, an effect which was independent of the nitrate supplied. Increase in the level of nitrate nitrogen in the nutrient solution has been found to reduce markedly the quantity of haemoglobin in the nodules. An account of this work is being published elsewhere.

In the Agricultural Botany section investigations on the role of boron in meristematic activity are being extended to include a detailed analysis of the main cell-wall components during the onset of boron deficiency. Investigations in this section have also been continued on two phases of growth of the potato : sprout growth during chitting and subsequent growth in the field. The length, diameter and dry weight of sprouts at the different positions on tubers in different size classes of two varieties (Arran Pilot and King Edward) were followed during chitting at 4° and 15°C. The apical sprouts were always larger with tubers kept throughout at 15°C but a smaller number developed than when the tubers were kept at 4° for three months before transferring to the higher temperature. Plants grown in the field from tubers with large sprouts emerged earlier and produced a greater total dry weight than did unchitted tubers. There was, however, an optimum sprout size (about 1.5—2.0 cm. in length) as shown by the above and by another experiment in which tubers were desprouted in February, at planting in April, and left with original sprouts. The first treatment had developed small sprouts again by planting and gave a higher yield than the tubers with original sprouts which were well advanced and from which many stolons developed into leafy branches. Those tubers desprouted at planting gave much lower yields.

An investigation is in progress on the contribution of mineral nutrients and carbohydrate to sprout growth. The relative influences on subsequent behaviour of the development over a long period of time under poor nutrient supply (as during chitting) have been compared with the faster growth made under high nutrient supply within a short period (as after planting unchitted tubers). This includes a quantitative study of the dry weight, nitrogen and carbohydrate changes and the rates of respiration and photosynthesis during the early stages of growth at three levels of nutrient supply and with two different initial sprout sizes. The effects of sprout size at the time of planting on emergence, leaf area changes and tuber initiation are also being determined in a constant environment. Sprout growth and the subsequent field growth and yield were found to be unaffected by variation over a wide range of light intensity and daylength during a chitting period of two months at 15°C. With longer chitting, differences in sprout elongation and axillary branching between the light treatments were found.

Results reported elsewhere in this report suggested that earlier tuber initiation can be achieved by planting at a high temperature and transferring to a lower temperature after emergence. A field experiment with the varieties Epicure and Ninety-fold confirmed this conclusion. Sprout emergence and tuber initiation were much earlier and the rate of bulking

faster in plants raised in the greenhouse and transplanted than in plants raised in the field. However, earlier senescence of these plants occurred as a result of the diversion of a higher proportion of the assimilate to the tubers. The influence of foliar applications of nutrients on such transplanted plants after tuber initiation is being investigated. An attempt to investigate resistance to, and re-growth following, spring frosts on these plants failed owing to the lack of natural frosts. This will be tried again in 1960, together with a detailed study of the temperature relations within a growing crop. Studies in growth rooms on the effect of frosts and also on the detailed changes in growth which result from a reduction in temperature to non-freezing levels are in progress.

A detailed study of the carbohydrate and nutrient relations of the terminal bud and of expanding leaves of the cucumber (cf. Ann. Report, 1958, p.34) has been commenced. Preliminary experiments suggest that neither the light supply to, nor the assimilation by, the terminal bud itself is concerned in the faster rate of leaf production induced by increased radiation.

Previous work in the Department of Agriculture on the agronomy of the potato crop—particularly in connection with water, seed treatment, varieties and depth, time and method of planting—has shown the need for knowledge of the effect of these factors on the growth and development of the potato crop in order to explain yield differences which occur. An extensive analysis of the growth of the potato crop, as affected by these factors, is at present in progress.

Studies on the ecology of the organism causing common scab of potato (*Streptomyces scabies*) and the mechanisms involved in parasitism are being made. Some observations are discussed elsewhere in this report. Various factors acting before and during the penetration stages have been found to be associated with the degree of expression of the disease. The surface microfloras of tubers of three different varieties of potato varying in resistance to scab were estimated. Total numbers of actinomycetes per unit area of tuber surface were higher and the incidence of total bacterial colonies was lower in susceptible than in resistant varieties. Comparison of tubers inoculated at different ages showed that the apparent number of lesions was proportional to the amount of tuber growth which had taken place. The changes occurring on the addition of organic matter are also being investigated. Studies on vesicular-arbuscular mycorrhiza in grasses are being continued (cf. Ann. Report, 1956, p.33). Particular attention is being paid to the methods of assessing

infection within a root system, the general relationships between the internal and external mycelial phases and the identity of the fungi involved.

From the series of investigations on the dormancy of charlock (*Sinapis arvensis*) seeds, which have been reported previously and are now being prepared for publication, the mechanism involved is envisaged as follows. In the soil, the embryos are fully imbibed and differentiated but they remain within the testa without further growth and development. The dormant state is regarded as a function of the oxygen tension in the seed. When seeds are at 1.0 atm. oxygen the coefficient of diffusion of oxygen into and through the testa layers is 2.8×10^{-12} cc. 0_2/cm.^{2}/sec. and the concentration at the embryo surface is only about 0.05 atm. To maintain oxygen at the centre requires 0.25 atm. 0_2 at the embryo surface as calculated from initial rates of oxygen consumption of excised embryos. An embryo enclosed by a testa consists of a superficial shell of oxygenated tissue and a mass of cells at the centre respiring anaerobically. The meristems which are the sites of cell division and extension are situated in the outer oxygenated zone. However, anaerobic metabolism of the cells of the central zone leads to the production of high concentrations of inhibiting substances which diffuse outwards and prevent the onset of growth.

Competition between perennial rye grass and meadow fescue over a range of densities is being investigated. A glasshouse experiment during the period December to April has shown that the greater aggressive nature of rye grass is associated with its higher capacity for tillering and accumulation of dry matter. A field investigation is in progress and will continue over several seasons. This includes plots of evenly spaced transplanted seedlings of the two species on which monthly counts of tiller and leaf number, and fresh and dry weights of the aerial parts, are being made. Results to date confirm those of the pot experiment. Studies on the intergeneric hybridization of these species have also been made. Eighteen naturally occurring plants of the sterile inter-generic hybrid *Festuca loliacea* taken from a hay field were examined cytologically and fourteen of them proved to be triploid. Comparative studies on the growth rates of certain of these hybrids in comparison with naturally occurring and selected strains of rye grass and fescue have been made under varying light, temperature and competitive conditions. The results suggest that rye grass of diploid hybrids would be successful under grazing conditions whilst the larger-leaved fescue or triploid hybrids would be favoured under " hay " conditions. Growth room experiments

showed that certain triploid hybrids could outyield selected strains of rye grass or fescue. The results are in agreement with the high frequency with which the triploid hybrid occurs in the population being considered.

A study of the survival of the Xasta mutant of *Drosophila melanogaster* has revealed that it is maintained in mixed populations at a high frequency giving rise to a condition of balanced polymorphism. Its maintenance is probably due to the complex chromosome constitution of the stock and the system is being examined further.

The crosses appropriate to a study of the genetics of leaf growth in tomato have been carried out and a detailed analysis will be made in the summer of 1960. In order to clarify the genetic control of the " ruptured epidermis " mutation of lucerne described earlier, F_1, F_2 and backcross generations of lucerne are being classified. The anatomical nature of this mutation is also being investigated.

In the Department of Agriculture, an analysis of the growth of wheat is being made to seek an explanation of the yield differences in winter wheat associated with different varieties, plant populations and nitrogenous fertilizers.

In the Department of Horticulture work is continuing on the effects of different water-regimes on the growth and yield of plants grown under glass. A new type of evapo-transpiration gauge has been developed for measuring the water used each day by 24 tomato plants grown at normal spacings. In the hot summer months of 1959 the amount varied from as little as 0.5 litres per plant on a dull day to more than 1.8 litres (over $\frac{1}{2}$ gallon) on hot bright days. The variation was found to be closely correlated with the amount of water lost each day from a series of evaporimeters suspended above the plants; these instruments seem likely to offer a satisfactory means of controlling the irrigation of tomato crops on a commercial scale.

The effects of light and temperature on the growth of lettuce, raspberry and other plants are being studied under controlled environments in a series of growth rooms, with special reference to the effects of environment on various phases of development. It is becoming apparent that the passage of raspberry plants from one phase to the next is only partly a response to changes in environment, since plants show an increasing tendency to move into the next phase with the passage of time even though environmental conditions are unchanged. Thus it is possible to explain phasic development in terms of a dual control by age and

weather. The change from one phase to the next can be accelerated by chemical treatments, gibberellic acid being particularly effective in stimulating shoots into growth under conditions where stem elongation usually ceases.

Studies are continuing on the effects of various drying conditions on the germination of vegetable seeds, and the results throw an interesting light on the patterns of seedling emergence occurring where various combinations of heavy rain and drying winds follow sowing in the field. Experiments, details of which are given later in this report, on the regeneration of plants from leaves and roots are showing that more use could be made of these methods of propagation where it is necessary to increase stocks of plants very rapidly. For instance, this method is finding a useful application in building up commercial stocks of plants from raspberries in which virus diseases have been inactivated by heat treatment.

Preliminary work is being carried out on a tropical species of economic importance but has not previously been grown on a plantation scale. A series of growth rooms is being used to study the effects of shading and various systems of watering on the rate of growth.

Factors affecting animal growth and production

The investigations on grassland in the Crop Husbandry section have continued along the lines described previously, both beef and dairy cattle being used in an attempt to evaluate pasture production more accurately. Identical twin dairy cattle have again been used to measure grassland production and its influence on milk composition (the latter in co-operation with the Dairy section). Indoor feeding trials with cut herbage have been carried out to ascertain, with greater precision than is possible in the field, the relation between herbage consumption and utilization by the dairy cow. It has been clearly established that, provided a reasonable level of herbage production is obtained, animal production from grassland is almost entirely dependent on stocking rate and the characteristics of the livestock. The implications of this in relation to techniques of measuring grassland productivity are being studied.

On the other hand it has been confirmed that digestibility of herbage is, within reasonable limits, unaffected by type of animal, breed, stage of lactation or level of feeding but is determined by characteristics of the

herbage. Techniques of herbage production are now being assessed in terms of output of digestible organic matter and its constituents, seemingly a more valid assessment than milk yields or live-weight gains which more frequently reflect characteristics of livestock than of the herbage.

In co-operation with the Agricultural Chemistry section, a long-term experiment is being made on the effect of various levels of roughage feeding during rearing on the ability of the dairy cow to utilize roughage for milk production. Use is being made of identical twin dairy heifers for this work. The first group of animals have completed their second lactation and further groups are in calf and in the rearing stage. The first group, on high- and low-fibre treatments from nine months to calving, showed no differences in milk production during their first lactation. Nevertheless, twins from this group, which were slaughtered early because of their poor yielding ability, have shown consistently that those raised on the high-fibre diet had a significantly larger rumen capacity (of the order of 20%) and marked differences in the nature of the stomach lining. In such stock it would seem, as has been suggested earlier, that milk production is limited more by the capacity of the mammary gland to utilize nutrients presented to it rather than by the ability of the digestive system to supply the nutrients.

Attempts are being made to improve the analytical procedures available at present for characterizing the fibrous and carbohydrate constituents of animal feed. A preliminary enzyme treatment has been developed which gives an unaltered fibre fraction of lower protein content than has previously been obtainable. Despite the advance which the advent of chromatographic techniques has brought about, the complete separation and accurate estimation of the individual carbohydrates occurring in plant material still leaves room for improvement. A method has been developed which, it is believed, affords improved separation and a more accurate estimate of these carbohydrates. The carbohydrates are extracted in fractions according to their solubility in solvents of increasing strength. The individual components of a fraction are separated by elution from a small ion-exchange column, and a fraction-collector has been built to cut the column eluate into fractions of selected volume which are analysed and the components estimated. The method has a wide application and is being used in the analysis of feeding-stuffs in an investigation of the relationship of these carbohydrate fractions with milk composition. As a further step in this aim an argon chromatograph is now in operation which will aid in the analysis of the fatty acids of milk fat.

Studies of the influence of " growth stimulants " on growth rate and carcase quality in beef cattle and sheep have been greatly expanded. Appreciation is again expressed for the facilities provided by co-operating farmers. The work with hexoestrol and diethyl stilboestrol continues and a wide range of additional compounds which include hydroxyzine tranquilliser, testosterone, progesterone and oestradiol are now under trial. The work also includes studies on physiological effects of hormones on other endocrine glands and the effect of sex hormones on nitrogen retention.

Injections of progesterone and Pregnant Mare's Serum have been successfully used for several years to produce autumn lambs from maiden sheep treated in March or April. However, attempts to induce out-of-season breeding in lactating ewes were unsuccessful due to a failure of fertilization, and the reasons for this are being further investigated.

Work on the influence of ovarian hormones on the composition of uterine fluids and on resistance to uterine infections has continued. Investigations on the effect of plane of nutrition on reproduction in sheep have now reached a stage suitable for publication; an account is given elsewhere in this report.

Facilities for the study of poultry and pig nutrition such as a new broiler house fitted to take 12 groups of 200 birds, a new temperature-controlled chamber for precise studies on caged birds, group and individual feeding accommodation for pigs, a metabolism unit and a field laboratory for preliminary analytical work are all being used by the Animal Husbandry section.

The effects of a variety of hormone treatments on carcase composition of both " Wiltshire " and " Heavy " pigs are under investigation and further information is being collected regarding the types of ration most suitable for the self-feeding of pigs to manufacturing weights.

The Animal Husbandry and Agricultural Chemistry sections are collaborating in a research programme concerned with the nutrition of pigs and poultry. The basic theme underlying this work is that in a determination of optimal nutritional requirements it is essential to define and regulate all variables. Particular attention is, therefore, given to the definition of environmental conditions, the complete analysis of all rations used, the standardization of circumstances of husbandry and the assessment of the quality of the end-product. Growth trials are supplemented with metabolic and nutrient studies and with carcass appraisal on dissection. Within this context an examination is being carried out of the effects of varying dietary energy level and energy-protein ratios on the

performance of " Wiltshire " pigs. This includes the definition of the optimum changeover period from a " starter " to a " finisher " type of ration. The potential feeding value of cereals with a high nitrogen content is also being studied.

The work on poultry nutrition is at present directed mainly towards the broiler and is concerned with the role of arginine, glycine and methionine in the nutrition of the young chick. A metabolic examination is being carried out of the participation of glycine and arginine in the synthesis of creatine. In the experimental broiler house an attempt is being made to define optimum levels of dietary energy and protein at different stages of growth.

Studies on other invertebrates, including insects

Investigations on the recolonization of the overburden from the Northampton ironstone workings have continued and an intensive survey of the Acarina and Collembola at three sites near Corby has been made. A large number of species have been identified including about 55 species of Mesostigmata, 16 species of Prostigmata, 26 species of Oribatei, 3 species of Acaridiae and 30 species of Collembola. These include two new species and an additional six which are new records for Britain. A number of soil analyses of the sampling sites have been made including mechanical analysis, pH and organic carbon. In addition, a botanical survey has been carried out. The agar-impregnating technique for the production of sections of undisturbed soil has been successfully modified for the very heavy clay soil at Corby; in this connection the assistance of the Geology Department in the design and construction of a new microtome is greatly appreciated.

An investigation has been commenced of the biological characterization of ' humus forms.' Some rendzina sites at Malham Tarn, Yorkshire, have been chosen for the initial phases of this work.

The study of the effects of population density on the increase in numbers in laboratory populations of the Rust-red grain beetle *Cryptolestes ferrugineus* Steph., a pest of stored products and especially wheat, has been completed. As might be expected, increasing the initial density depresses fecundity and rate of development and increases mortality. The mechanism responsible for these changes has not been elucidated but the results point to the importance of cannibalism at the higher densities. Estimations of ' actual rate of increase ' of the population suggest that fecundity is the dominant factor at low density, and rate of development at high density.

Work has been continued on the nutrition and cytochemistry of *Trypanosoma theileri* Laveran, a species occurring in cattle in the British Isles, and *T. lewisi* Kent, a parasite of rats. Both species have been maintained in culture in the laboratory and attempts have been made to culture them in semi-defined media.

The survey of aphid populations in potato crops in the Isle of Man, carried out in co-operation with the Manx Government, has been continued. *Myzus persicae* Sulz. was again the predominant species; *Macrosiphum solanifolii* Ashm. and *Aulacorthum solani* Kltb. were generally present, and occasionally *Aphis fabae* Scop. and *Myzus ornatus* Laing.

Microbiological Studies

Work on microbiological fats has been continued and the results arising from it have been published elsewhere. The nutritional and physiological needs of the yeast during the " fattening " phase have been defined with somewhat greater precision. New work has been initiated on heterotrophic growth and fat production.

Studies on the Corynebacteriaceae of interest in agriculture have been continued and have now been extended to include *Listeria monocytogenes.* Work has also commenced on the mineral nutrition of the Rhizobiaceae and on the effects of sub-lethal heating on spoilage and pathogenic micro-organisms. Studies on the surface sterility of metals have been published; these have now been extended to include the activity of surface films of bactericidal substances.

Farm Management Studies

During the past year routine investigations into farm incomes and into costs of different farm enterprises have been continued. These have included a study of factors affecting the adoption of new farm practices and of the economies of scale possible in commercial egg production. The study of production functions referred to in the Annual Report for 1958 has continued, considerable use being made of the electronic computer at the Rothamsted Experimental Station.

Studies on the economic evaluation of new accommodation for dairy cows in the East Midlands and on the profitability of particular systems of beef production are nearing completion. Work has continued during the summer of 1959 on the problem of measuring the response to fertilizer application of permanent grass for beef production and a summary of the findings is included elsewhere in this report.

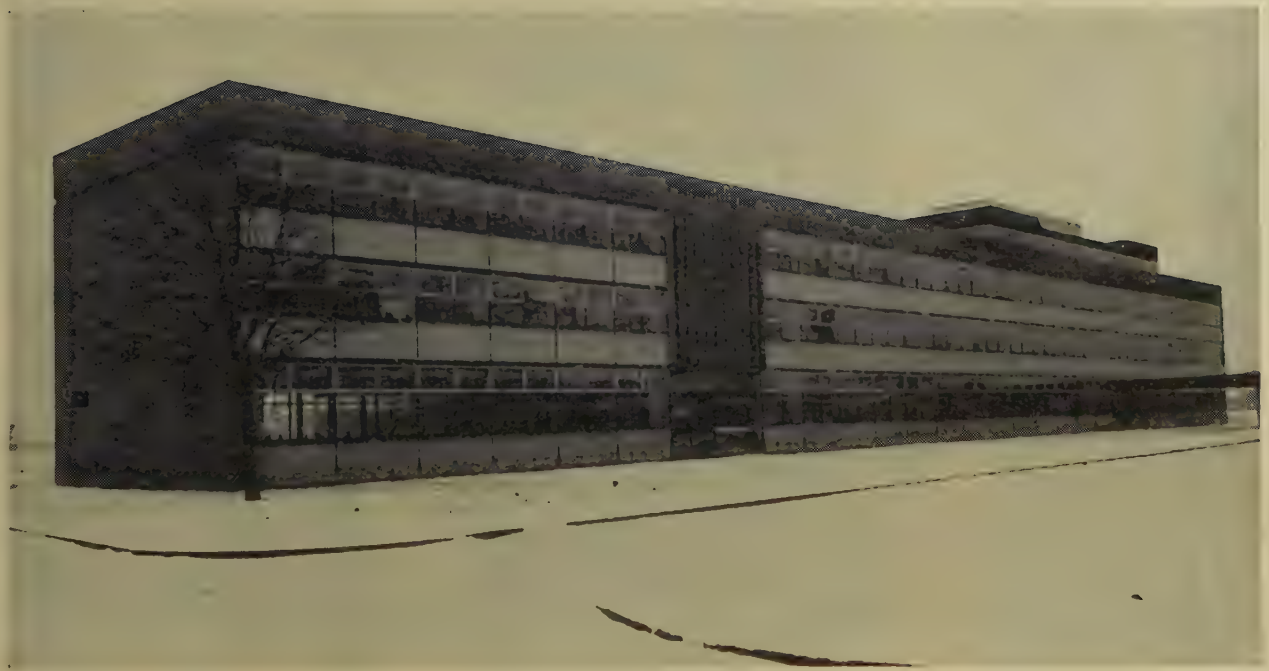


PLATE 1. The Agricultural Sciences building.
(With acknowledgements to Raymonds News Agency, Derby)

THE AGRICULTURAL SCIENCES BUILDING

E. G. Hallsworth

The new Agricultural Sciences building (Plate 1), opened on the 15th January, 1960, by Sir William Slater, K.B.E., D.Sc., F.R.S., contains laboratories for teaching and research in the Agricultural Botany and Agricultural Chemistry sections of the Department of Agricultural Sciences, and for the Crop Husbandry and Animal Physiology sections of the Department of Agriculture.

It is sited on the north-east boundary of the existing group of buildings and is planned as a simple rectangular block 290 feet long and 40 feet wide, three storeys high, its long axis running approximately north and south and parallel to the existing group of buildings. There is a single-storey wing on the east side for the hydrology laboratory whilst the animal houses and plant growth rooms extend as a third floor over half of the length of the building.

The construction and finish of the building involve a variety of concrete techniques. The frame consists of pre-cast concrete perimeter columns with a spine wall cast *in situ* supporting floors constructed with pre-cast pre-stressed beams. Externally, the spandrel panels consist of pre-cast planks with Derbyshire spar aggregate exposed in the facing which spans between the columns. The parapet was formed *in situ* with an exposed grey granite aggregate. The staircases and entrance halls are also constructed in pre-cast concrete containing small black granite chips in the aggregate. Construction was begun in May, 1957, and completed in September, 1959, the architects being Basil Spence and Partners and the contractors Messrs. Laing & Company. The design of the laboratories and their disposition within the building were executed by members of the staff of the Departments of Agricultural Sciences and Agriculture.

Two main entrances open into the block. Undergraduates going to the teaching laboratories on the ground and second floors use the north entrance (Plate 2), whilst research and final year honours students and staff use the south entrance (Plate 3). A minor entrance exists under the south staircase giving convenient access to the research and demonstration plots which are to be developed between the building and the buildings of the Experimental Farm. A service entrance is placed at the rear of the building, the roof of the unloading bay connecting the main building with the hydrology block. The working area of the building is

PLATE 2. The north (undergraduate) entrance.

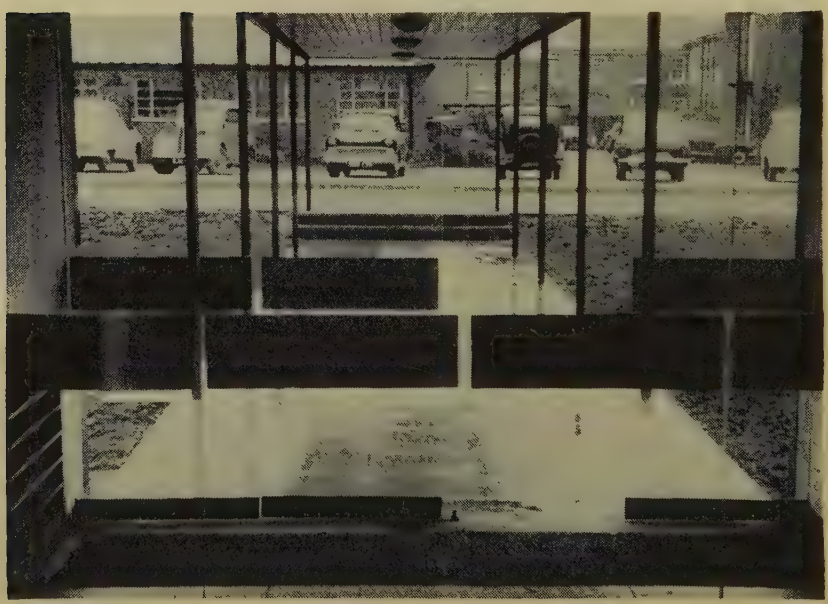


PLATE 3. The south (staff) entrance.

29,624 sq. ft., and the circulation area (corridors, staircases, ducts, toilets, etc.) is 5,770 sq. ft., giving a total gross floor area of 35,400 sq .ft. This was built at a cost, including the benching, fees, etc., of approximately £250,000.

The ground floor provides for two large teaching laboratories for Agricultural Chemistry (Plate 4), situated on either side of the undergraduate entrance. Grouped around the graduate entrances are services rooms for the preparation of soil and plant material, workshops and the research laboratories for Crop Husbandry and Soil Physics.

The first floor is devoted entirely to research laboratories for Agricultural Chemistry and Animal Physiology and includes separate laboratories for spectrographic and X-ray analysis, and one for the use of radioisotopes, as well as a range of cold rooms.

On the second floor, on either side of the north staircase, are two teaching laboratories for Agricultural Botany (Plates 5 & 6) and Agricultural Zoology; the rest of this floor providing research laboratories, including a suite of constant temperature rooms for Plant Physiology, Plant Pathology and Genetics.

The teaching laboratories have been designed to carry up to 48 students in each laboratory at a time, the design of the benching being suited to the most common purpose. In the Chemistry laboratories each working space is provided with gas, water, A.C. electricity and a vacuum tap for filtrations, etc. The central sink has both hot and cold water for washing apparatus, and a large polythene demountable silt trap to keep the drains free from the soil which inevitably would slip into them. The heights of the laboratories show reductions on those conventionally used. The ceiling is 10 ft. from floor level on the ground floor and 9 ft. on the other two floors. The ceilings are completely plain and free from any obstruction other than fittings for the lights, allowing in the large laboratories a natural draught from the windows on one side to the other. The windows themselves are continuous and deliver air at ceiling height along the entire length of the building. The floors of the laboratories are covered with P.V.C. tiles in two shades of mottled grey, ceilings are painted light grey-white, and the walls in pale dove-grey.

The corridors on all floors are paved with cork blocks to minimise noise. The corridor wall opposite the spine wall where research laboratories are located is framed in meranti, with doors in natural beech veneer and chipboard panels painted grey.

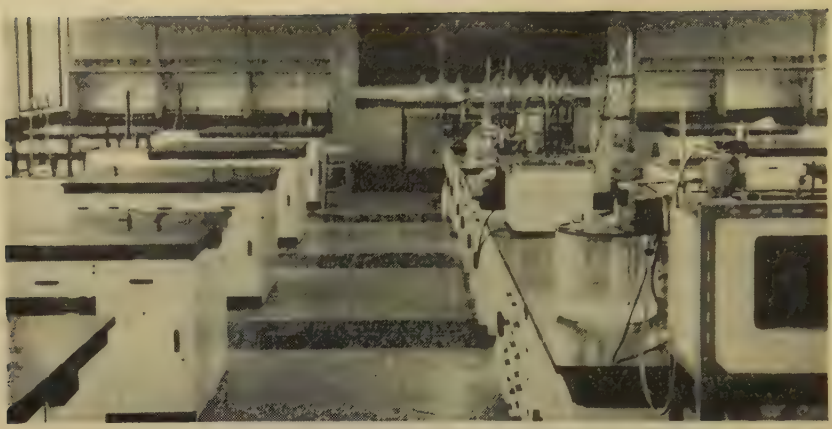


PLATE 4. Teaching Laboratory for Agricultural Chemistry.

PLATE 5. Teaching Laboratory for Plant Physiology.
(With acknowledgements to Raymonds News Agency, Derby)

PLATE 6. Teaching Laboratory for Agricultural Botany.
(With acknowledgements to Raymonds News Agency, Derby)

Since the need for space for different aspects of work is likely to change from time to time, an attempt has been made to make the accommodation as flexible as possible by adopting a wall construction, service distribution and type of benching that allow easy alterations within relatively broad limits. Except for the spine wall and the walls at either end of the main laboratories, the space available has been divided by plaster board partitioning which can be easily cut, removed or re-erected. The use of ceiling heating, by low pressure hot water pipes set behind the plaster, removes one of the hindrances to such redevelopment. Flexibility for the services has been achieved by concentrating them in main ducts running the length of the building below floor level on the ground floor, and over the ceiling of the corridors on the floors above. From the main ducts run branch ducts in a broad herring-bone pattern. Both main and branch ducts have removable covering panels (Plate 7). The services are then distributed on each floor by a duct (Plate 8), running around the perimeter, faced with demountable panels in chipboard and topped with irriko polished to match the bench tops.

The fume cupboard system is based on a unit cupboard 4 ft. long, the sides, back and top being made of fibrous asbestos sheet. In most no front window is fitted, but the rear wall is hollow and air is drawn in by slots at the top and bottom fitted with a sliding shutter allowing the width of the slit to be altered from 0 to 3 inches. Suitable adjustment of the slit width consequently enables the draught to be equalised between the top and bottom of the cupboard. These adjustable slits also cause the draught to be equalised between the different cupboards when more than one cupboard is attached to one fan. In most laboratories two cupboards are attached by a duct to the fan and motor which are housed in fan houses on the flat roof. All the ducting is in unplasticized P.V.C. and the bench tops covered with lead sheet. Each fume cupboard draws 500 cu. ft. per minute; if all those in each Chemistry teaching laboratory are operating, the laboratory experiences a complete change of air once every three minutes forty seconds. To compensate for heat losses in winter from this rather rapid turnover, a hot-air make-up system has been installed which is switched on automatically with the exhaust fans.

All the benching is carried on metal supports and fitted with standard interchangeable underbench units made in cream-enamelled steel. It is completely demountable, and in fact one-third of the benching and fittings has been transferred from the various temporary laboratories erected since 1952. The balance benches are made of a series of separate reinforced concrete blocks, each three feet long, six inches thick, separated from each other and from the brick piers supporting them by a half-inch

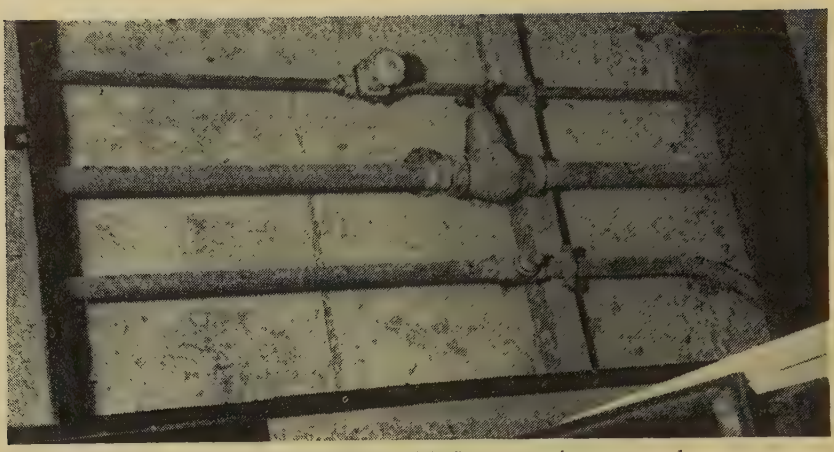


PLATE 7. Service ducts with floor covering removed.

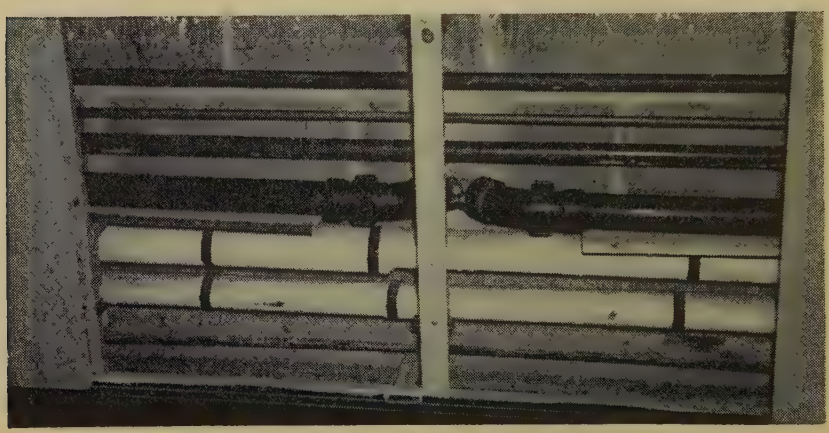


PLATE 8. Service ducts with wall panelling removed.

PLATE 9. Balance room (experimental glasshouse in background).

thick strip of cork; the mass of each block provided sufficient damping (Plate 9). In the cold and constant temperature rooms the shelving is of expanded metal. On the third floor there is a small-animal house consisting of several rooms, each capable of being maintained at different temperatures to suit the rats, rabbits and chickens required for biochemical physiological research, and a food store, preparation room and a small operating theatre.

Also on this floor is a group of six plant growth rooms in which plants can be grown under light intensities up to 2,000 ft-candles, with varying day-lengths and with different day and night temperatures, but no attempt is made to control humidity. Both the growth rooms and animal house are connected by the service lift to the research laboratories which need them and which are situated conveniently below.

Certain features of the building are perhaps worth additional comment. By locating the plant growth rooms, the constant temperature rooms and the cold rooms one above the other it has been possible to make considerable economies in the space required for their specialized services; for example, all the compressors are housed in one small room in three banks.

The radio-isotope laboratory provides a preparative section and a screened-off counting section. In the construction considerable use has been made of lead sandwich consisting of a sheet of 8 lb./sq. ft. lead sheet held by a plastic adhesive between two sheets of plywood. This eliminates, to a considerable extent, the creep that would otherwise inevitably occur through changing temperature when lead sheet is hung vertically.

The optical apparatus room includes separately-partitioned cabinets for the spectrophotometer and for the polarising microscope. A small dark room solely for the use of this equipment is placed between the X-ray and the large Littrow spectrograph (Plate 10).

Apart from the greatly improved facilities for what might be taken as the more usual aspects of the course work, this building has allowed a considerable development of teaching in animal physiology and in soil physics. For example, the new animal physiology laboratories allow students to carry out experiments on factors influencing the activity of nerve, blood, and muscle tissues and to measure basal metabolism and the rate of respiration. The soil physics and hydrology laboratories are intended to demonstrate the movement of water both in channels and through porous media, as well as the transport of solid particles by fluids.

PLATE 10. Spectrograph.
(With acknowledgements to Raymonds News Agency, Derby)

In these laboratories sand tank models have been built to illustrate some classical patterns of water flow, whilst a 30-ft. wind tunnel allows for the reproduction of wind transport effects at speeds of from 4 to 25 m.p.h. Other items include a well-equipped workshop, a room for the preparation, drying and grinding of plants or plant materials, another for drying and grinding soil, a photographic studio, and the usual addenda. It seems possible that, taken as a whole, the facilities provided by this building for teaching the chemical, botanical and physiological principles which underlie agricultural science compare more than favourably with those of any other university of the Commonwealth.

THE SIXTH EASTER SCHOOL IN AGRICULTURAL SCIENCE

APRIL 13th—16th, 1959

THE MEASUREMENT OF GRASSLAND PRODUCTIVITY

J. D. Ivins

Grassland of some kind occupies virtually two-thirds of the area of Britain alone and in many other parts of the world it is equally, or even more, important. New varieties of herbage plants have been produced and new methods have been developed which have resulted in great increases in the production of herbage, but a constant problem has been the development of techniques for its measurement and for comparing its productivity under different conditions and treatments. The Sixth Easter School in Agricultural Science, attended by some 130 scientists from 12 countries, was devoted to a consideration of these techniques. The purposes of the School were to provide an opportunity for an exchange of information and experiences, to assemble ideas, and to consider the limitations of particular techniques and the conditions under which they might be used to advantage. Several contributors chose to illustrate these principles by a description of their own work and the results they obtained naturally led to discussions on wider aspects of grass production and utilization.

In the opening session Dr. William Davies (Grassland Research Institute) reviewed the evolution of grassland research techniques and Professor E. Klapp (University of Bonn), outlined developments during the last 20 years in Germany. A paper by Mr. R. P. Hawkins (National Institute of Agricultural Botany) on the preliminary classification of herbage varieties was followed by a description of the effects of varietal characteristics of herbage plants on their agronomic value by Mr. Ll. Iowerth Jones (Welsh Plant Breeding Station). Mr. J. Warren Wilson (University of Reading) described a point-quadrat technique for the analysis of the distribution of foliage area and Mr. J. O. Green (Grassland Research Institute) discussed clipping techniques for the measurement of herbage production. The value of such measurements in animal production experiments was considered by Mr. C. Line (National Institute for Research in Dairying), followed by Mr. J. Davison (University of Nottingham), who gave an account of experiences in the assessment of herbage consumption by livestock at Sutton Bonington. This session was concluded by Mr. J. Lowe (Minister of Agriculture, Northern Ireland), who reviewed the techniques which had been used and the

results obtained over several years for the determination of herbage production and consumption by livestock in grazing trials in Northern Ireland.

The effects of ley composition and management on the yields of subsequent arable crops were described in detail by Mr. T. E. Williams (Grassland Research Institute) in a separate evening session.

As grass is grown to feed livestock, the techniques which bring livestock production into the final assessment of grassland were given major consideration and eight papers were devoted to this aspect. Mr. F. E. Alder (Grassland Research Institute) opened this session with an account of pasture experiments with animals at Hurley and Professor W. Holmes (Wye College, University of London), discussed the relationship between animal production and feed intake of animals at pasture—a theme also followed by Dr. D. S. McLusky (University of Durham). Dr. P. Boeker (University of Bonn) critically reviewed the Falke-Geith (utilized starch equivalent) method of pasture evaluation and Professor J. D. Ivins (University of Nottingham) discussed the interpretation of animal production data in grassland evaluation in the light of the results of experiments at Sutton Bonington. Mr. F. Raymond (Grassland Research Institute) dealt with the particularly important subject of nutritive value and digestibility of herbage and Mr. J. Davison (University of Nottingham) gave the results of digestibility trials with dairy cows. The experiences at Ruakura with the chromium techniques for estimating faecal nitrogen were described by Mr. R. J. Lancaster (Ruakura, New Zealand).

A subsidiary problem, the measurement of grassland productivity on a farm scale, was considered. Two different principles were involved: one based on utilized starch equivalent and introduced by Mr. J. Clark (I.C.I. Central Agricultural Control); the other based on stock carrying capacity (cow grazing days) and elaborated by Mr. Rex Paterson, who had used this system for 16 years on his farms in Hampshire.

The full proceedings were published in December, 1959, by Butterworths Scientific Publications, London, under the title "The Measurement of Grassland Productivity," price 35s. 0d. per copy.

GRASSLAND VALUES ON THE FARM

POSTSCRIPT TO THE SIXTH EASTER SCHOOL IN AGRICULTURAL SCIENCE

J. D. Ivins

Although the object of the Easter School was to discuss the use of techniques for grassland evaluation primarily in relation to research, certain principles emerged which have a direct bearing on grassland farming. In all 20 papers were read; the following points arose from four of these papers together with some later findings on digestibility.

The advantages of recording the output of grassland on a farm scale were apparent from the deductions which it was possible to make from such records. The effects of fertilizers, the comparative production of contrasting swards, the effects of age on the yield of leys and the milk-stimulating value of particular feeds, could all be evaluated under farm conditions. Whatever system of recording is adopted there are limitations, but some measurement of grassland productivity or of the production of a system of farming—for example livestock on grass as assessed by the utilized starch equivalent method—must surely be the basis for improved utilization of grassland on the farm. Without such records we can only grope and guess.

The limit to animal production from grassland may be set by the pasture or by the livestock. On a national scale the limit is likely to be imposed by the species of herbage plants, much of our grassland having species with a short season of growth and producing material of low digestibility and nutritive value. However, on farms where grassland productivity has been intensified there may be circumstances where the livestock, because of low stocking rate, stage in lactation, health, management or low animal potential through breed or breeding, have set the limit to animal production from grassland. Attention to these factors of animal production may frequently increase the utilization of herbage with no further sward treatment. Intensity of stocking has been found to be a supreme factor in determining milk yield or liveweight gains where grass production is at a high level.

The digestibility of herbage, namely that portion of the feed which does not appear in the faeces, is an important characteristic which is now receiving considerable attention. Species and varieties of herbage plants vary considerably in digestibility and vary correspondingly in their value to the animal. For example, in terms of percentage digestible organic matter the rye grasses have proved superior to cocksfoot by some 5%

or 6%, lucerne is of relatively low digestibility being some 10% lower than grasses of similar crude protein content. Depending on the species, the grasses generally are of high digestibility until the time of inflorescence emergence when digestibility starts to fall rapidly, day by day, as the plant matures to seed. It has been found that S.24 ryegrass may give herbage of between 80% and 85% organic matter digestibility until flower heads emerge, after which this figure falls rapidly to less than 60% by mid-June. This phenomenon is of importance in relation to the time of cutting for conservation or to the stage of growth for grazing. Incidentally, at the Grassland Research Institute, Hurley, white clover and lucerne were found to be the constituents of the ley responsible for increased fertility as measured by the yields of wheat crops following the ley, but when we consider the phenomenon of digestibility our respect for white clover grows beyond its connection with nitrogen accumulation and the production of protein-rich herbage. While we have been inclined to value herbage on the basis of its content of crude protein (Nitrogen × 6.25) there is little, if any, relationship between crude protein content and digestibility and the animal seems more responsive to herbage of high digestibility. Young grass and white clover frequently have a high content of crude protein (20%—25% of the dry matter) and are of high digestibility, but mature grass may be made to have a high content of crude protein by treatment with nitrogenous fertilizers and yet be of relatively low digestibility.

A particular sample of herbage is digested to virtually the same extent by dairy cattle regardless of breed or level of milk production and it appears that sheep and bullocks have a similar digestive efficiency to dairy cattle. The latter can only achieve high milk production from grass, whether fresh or conserved, provided that the material is of high digestibility. Consequently, the level of animal production which we hope to obtain from grassland must determine the techiques of grassland farming and not vice versa, particularly in so far as these techniques—such as species and varieties with their differing flowering dates and the stage of growth when utilized—are known to influence the digestibility of herbage. Thus we should endeavour to have our first cuts of herbage safely ensiled before the end of May, for the flowering dates of grasses are determined primarily by length of day and this we can predict.

Comparisons of grassland treatments in terms of total quantities and seasonal production of digestible organic matter and its constituents are now being made and promise to be of great value; for whereas milk yields and liveweight gains are often largely determined by the animal, on occasions irrespective of the herbage, digestibility has proved to be a characteristic of the herbage and an index of its value to the animal. So

close is the relationship between herbage characteristics and digestibility that it may prove possible for digestibility to be predicted from examination of the plant tissues under the microscope. For example, the relatively low digestibility and palatability of cocksfoot is attributed to the silicified dentations along the margins and midribs of the leaves, and plant breeders in Holland have selected smooth-leaved cocksfoot, thus providing greater possibilities with this drought resistant and productive grass.[1]

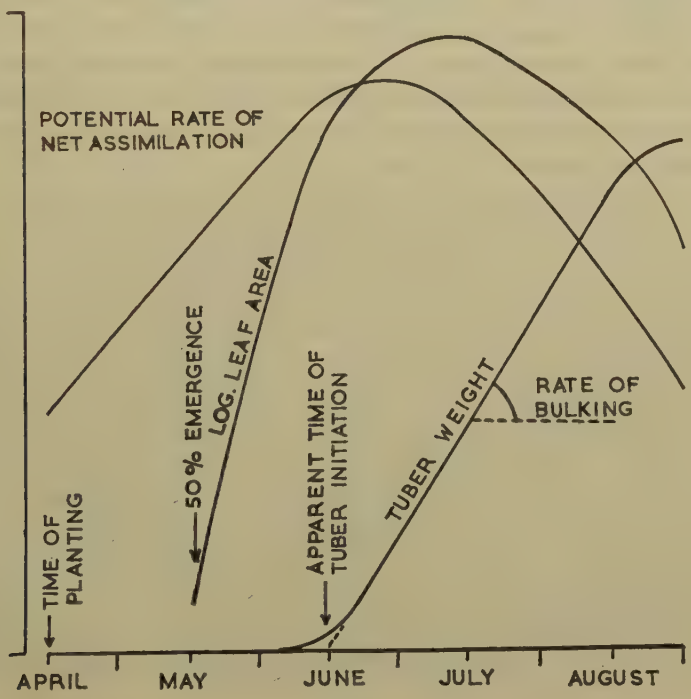
REFERENCE

(1) DIJK, G. E. VAN. (1959). Breeding for quality in cocksfoot. *Euphytica.* **8**: 58-68.

THE GROWTH OF THE POTATO PLANT

M. N. Borah and F. L. Milthorpe

The main growth features of the potato plant are shown in the accompanying generalized diagram which is drawn on a time scale typical of main-crop varieties in the Midlands. One point of interest is that the maximum leaf area is reached slightly later than the peak of the potential rate of net assimilation. The latter is taken from the work of Watson [1] and is a measure of the possible rate of photosynthesis as determined by the temperature and light available. Tuber initiation com-



mences near the time of maximum assimilation rate and maximum leaf area, and the growth of the tubers occurs at a time when the net assimilation rate and the leaf area are decreasing. Under most circumstances the curve of tuber weight with time shows three phases : (i) a period of about 10—14 days after tuber initiation when tuber weight increases exponentially with time; (ii) a long period (up to 6—8 weeks) when it increases linearly with time; and (iii) a final phase of decreasing growth rate associated with senescence of the leaves. A straight line fitted to the yield of tubers with time during the second phase gives two parameters of great interest—the *rate of bulking* provided by the slope and the *apparent time of initiation* given by extrapolation of the line to the time when the weight was zero.

The main problem involved in increasing tuber yields is to displace the tuber curve towards the left, i.e. to obtain earlier tuber initiation, higher rates of bulking and to prolong the duration of the period of constant bulking rate. The present series of investigations is concerned with these problems and in understanding the interrelations between the various processes of growth and the ways in which they are influenced by weather factors. These experiments were carried out with the variety Arran Pilot in pots outside and inside a glasshouse and in plant growth rooms to provide a wide range of levels of temperature, radiation and length of day. Water supply has been kept at a high level throughout; its important effects are not considered here. Tubers with sprouts 2—3 cm. long were always planted : work which will be reported later has shown that the time to emergence and tuber initiation is shortened by an increase in the length of sprout at planting up to about 1.5 cm. but not with longer sprouts.

The time taken for plants to emerge was considerably shortened by high temperatures after planting; over the range from 56°F to 72°F the time to emergence was increased by one day for every increase of 1°F. The time from emergence to tuber initiation was influenced by the length of day, by light and by temperature. A great deal has been written about the influence of daylength on the growth of the potato but much of this is very confused. In our experiments the time from emergence to tuber initiation was only about three days less with a 12-hour than with an 18-hour day, and this advantage was soon lost as the rate of bulking was lower in the short than in the long days. There appears to be no physiological basis for the generally accepted classification [2] that European maincrop varieties are day-neutral with a tendency towards the short-day type because they form their tubers under the declining daylengths of autumn whereas early varieties more nearly approach the long-day type. This classification is purely agricultural being based on

the usual growing seasons. All European varieties would appear to be similar—they are effectively day-neutral with a tendency towards short-day reactions—although many wild species are known to be quite definite short-day plants. In this country no variety in any district experiences daylengths less than 15 hours at the time of tuber initiation and there would appear to be no advantage in arranging exposure to shorter days.

The main weather factors which influence the time between emergence and tuber initiation are temperature and intensity of radiation. Under constant conditions, tuber initiation at 68°F was one week earlier than at 59° and three weeks earlier than at 77°, and was about two weeks earlier with a high than with a low level of radiation. Similar responses were found with different night temperatures associated with a constant day temperature of 68°; initiation was later with night temperatures of 50° and 77° than with night temperatures of 59° or 68°. In the fluctuating conditions in a glasshouse or in the open, initiation was hastened by an increase of the mean daily radiation (over the range 70—370 cal. cm^{-2} day^{-1}) and of the mean day temperature (62°—76°F) and by a decrease of the mean night temperature (55°—65°F).

These responses were closely associated with differential growth of the various organs. The growth of the haulms was fastest with high temperatures and high radiation. Under these conditions, those primordial leaves which were already present at planting and which emerged above the ground (about 16 of the total 23) expanded rapidly and the growth of axilliary branches was promoted. Much of the assimilate was used in the growth of these many centres of activity. At the lower temperatures of 59° and 68°, haulm growth was less rapid, there was less axilliary branching and each leaf expanded to a larger size. After the first two to three weeks following emergence the total amount of assimilate produced was as great at 68° as at 77° and less of it was used in producing haulm growth or stolon growth. The concentration of carbohydrates at the stolon tips would therefore be expected to be higher; this it is believed stimulated tuber initiation. It was certainly not true that less carbohydrate was available in the whole plant at the high temperature due simply to the differences between the rates of photosynthesis and respiration, as has been suggested previously.[3] [4] There was a greater addition of dry matter per unit present at 77° than at lower temperatures but more of it was used in haulm growth. Tuber initiation, therefore, was hastened by an intermediate temperature (59°—68°) and a high level of radiation but the greatest number of tubers was formed over a short period of time at the lowest temperature. Similar responses appear to occur in response to fertilizers, where high levels of nitrogen stimulate haulm growth and retard tuber initiation.

The rate of bulking was greatest where an intermediate number of tubers were formed as at 68° constant or 68° day with 59° night temperature. Where many tubers were formed, growth was not as rapid as where there were fewer; where very few tubers were formed the growth of these tubers was very rapid indeed. The optimum temperature would appear to be in the region of 60°—65° because this offers the most satisfactory resultant between a large number of conflicting growth processes whereby the greatest amount of assimilate is diverted into tubers. Higher temperatures lead to more rapid top growth and depress tuber initiation; lower temperatures result in slower growth and low total assimilation capacity of the plant, leading to the initiation of a large number of tubers which increase slowly in size. The temperature which is optimum for growth will, however, change with the stage of growth. Between planting and emergence, high temperatures are advantageous to give rapid emergence; then, lower temperatures (60°—65°) will lead to the most rapid initiation of tubers. Once the tubers have started growing, somewhat higher temperatures and higher levels of radiation would be expected to be advantageous in order to ensure the maintenance of a large leaf area over a long period of time.

One effective way of obtaining earlier tuber initiation is suggested by these results. This is to allow the plants to emerge at high temperatures (as under glass) and then to transplant to the lower temperatures existing in the field. Preliminary experiments have shown that this leads to initiation about a fortnight earlier but haulm growth is also checked and bulking proceeds at a high rate for only a short period. These investigations are being continued.

The rate of bulking appeared to be largely independent of both the area of leaf surface present and the rate of assimilation during the period of bulking. It appeared to be most closely correlated with the conditions over the first two weeks following the commencement of tuber initiation. These determined the number of potential growing tubers and the rate at which they subsequently increased in size. It is likely that the soil temperature over this period would influence the rate but this has not yet been investigated. However, it would appear that the rate of bulking is not determined by the amount of assimilate available during the period of rapid growth of the tubers; this can be met by a leaf area of 3—4000 cm^2 per plant (leaf area index of 1). The maintenance of the leaf surface at this level is important, however, as a decrease to one-quarter or one-third of this amount, as occurs with rapid defoliation by blight or frost or from senescence, results in a marked decrease in the rate of bulking. Although there is little evidence on the duration of cell

division in tubers, that available suggests that division (and therefore tuber growth) can proceed for a very long time provided the leaf surface is maintained and the plant does not experience a shortage of water.

REFERENCES

(1) WATSON, D. J. (1952). The physiological basis of variation in yield. *Advanc. Agron.* **4**: 101-145.

(2) DRIVER, C. M. and HAWKES, J. G. (1943). *Photoperiodism in the potato.* Cambridge: Imp. Bur. Plant Breed Genet.

(3) BUSHNELL, J. (1925). The relation of temperature to growth and respiration in the potato. *Tech. Bull. Minn. Agric. Exp. Sta.* No. 34.

(4) WERNER, H. O. (1934). The effect of a controlled nitrogen supply with different temperatures and photoperiods upon the development of potato plant. *Res. Bull. Neb. Agric. Exp. Sta.* No. 75.

THE PROPAGATION OF PLANTS BY LEAF CUTTINGS*

Margaret E. Marston

Vegetative propagation is practised to produce plants genetically identical with a selected individual. Many of the perennial crops of the world are propagated vegetatively to perpetuate outstandingly good varieties, such as heavy yielders or ones particularly suited to local conditions. Where a well-proven variety subsequently degenerates due to a virus and the virus can be inactivated by a specific treatment, a healthy clone can be re-built by giving this treatment to a few individuals and then propagating vegetatively from them.

There are a number of different methods of vegetative propagation but species differ in their ability to regenerate from isolated parts of their shoot and root systems. When the propagator has an option, the method chosen depends on a number of factors, including number of plants to be raised, the quantity of propagating material entailed, the environmental conditions required, and the time which will elapse before the desired plants have been produced. The number of new plants resulting from one cutting, and their physiological stage of development, differ according to the type of cutting used. For instance, adventitious roots develop on stem cuttings and thus the propagating material itself becomes incorporated in the single plant that is produced. In propa-

* In horticulture the term "leaf cutting" is used for all or part of a leaf taken from a plant, without the axillary bud and without any part of the stem, for the express purpose of propagation.

gating by leaf cuttings, however, the original leaf forms roots but generally does not become part of a new plant, since adventitious shoots with their own root systems develop into a number of progeny which become independent of the parent leaf.

Practically all species can regenerate from stem cuttings but only a limited number appear to respond to attempts at propagation by root or leaf cuttings. Nevertheless, more precise knowledge concerning the selection of material and the environmental conditions required for successful propagation may extend this restricted range. Hudson,[1] for example, has shown that in raspberry, *Rubus idaeus*, there is an " on " season for successful propagation by root cuttings and that cuttings taken in the " off " season are likely to fail under all environmental conditions.

The use of detached leaves in plant propagation is at present confined to certain tender herbaceous species; of these a very few regularly develop progeny on their leaves as part of the natural life cycle, but others may be induced to do so by using leaf cuttings. The advantages of leaf cuttings are twofold: a number of progeny are generally produced from each leaf and the source plant need only lose a few leaves. Leaf cuttings are, therefore, of importance where a large number of progeny is required from a small amount of plant material as, for instance, in the bulking-up of plants from one selected individual. In the late 19th and early 20th century much interest was shown in propagating plants from leaves but many of the species then used are now of botanical rather than of horticultural interest. Hagemann[2] reviewed the literature dealing with the development of roots and/or shoots from leaves and since then there have been additional valuable contributions, but little critical quantitative work has been done with leaves detached from a plant and grown in order to produce progeny.

Experiments have, therefore, been carried out with *Streptocarpus* x " Constant Nymph " to study some of the more fundamental aspects of regeneration from leaves. *Streptocarpus* is a genus also used in other fields of research work and is particularly suitable for experimental work with leaf cuttings on account of its outstanding regenerative capacity and because it possesses long leaves, each of which can be cut to form a number of leaf cuttings. The morphology of *Streptocarpus* is not typical of a dicotyledon since from the base of each leaf, and attached to it, 4-6 flower stalks arise and proximal to this " flowering-region " a new leaf develops. There is no apparent stem or growing point. At the outset it was found that detached leaves in which the flowering-region was retained behaved differently from those in which it was removed (Plates 1, 2 and 3). It is thought that the former were essentially " leaf-

PLATE 1.

Flowers but no progeny developing at the base of a leaf of *Streptocarpus* x "Constant Nymph" which was cut to include the flowering-region.

PLATE 2.

Progeny developing at the base of a leaf of *Streptocarpus* x "Constant Nymph" which was cut to exclude the flowering-region.

PLATE 3.

Progeny developing at the base of an apical portion of a leaf of *Streptocarpus* x "Constant Nymph".

PLATE 4.

Unusual type of new growth and inflorescence axes (removed for photographing) produced by a leaf cutting from which the flowering-region had been removed.

bud cuttings " i.e. leaves detached in such a way that the axillary bud and a portion of " stem," although not visible, must have been included. Work continues on this phenomenon and the anatomical structure of the basal part of the leaf is being investigated.

A study of the total nitrogen in detached leaves of *Streptocarpus*, which were cut above the flowering-region and inserted in vermiculite (a propagating medium containing no nitrogen), showed that over a period of three months the total nitrogen initially present in the leaf became re-distributed throughout a closed system, consisting of inserted leaf, the root system produced by the leaf and the progeny which formed at the base of the leaf; little or no nitrogen being lost from this system. However, the amount of nitrogen available for the development of progeny during the period of dependence on the parent leaf may not have been adequate for optimum growth.

A further experiment was, therefore, designed in which entire leaves, basal and apical halves were inserted in a medium without nutrients and later transferred to a standard compost, John Innes Potting Compost No. 1, which contains fertilisers and is widely used in horticulture for pot plants. (Plants of *Streptocarpus* have been successfully grown in this compost for a number of years.) The results were unexpected. Most of the entire leaves and basal halves regenerated new tissue at the proximal cut surface. This was unlike any new growth encountered in earlier experiments, and, furthermore, these leaf cuttings developed flowers although the flowering-region had been removed at detachment of the leaves from the plant (Plate 4). But the production of progeny was suppressed; instead, new leaves developed proximal to the regenerated tissue. In contrast, most of the apical portions formed progeny although a few of the youngest portions regenerated new tissue but did not produce flowers. More work is required to determine the precise conditions under which this phenomenon of regenerating new tissue occurs. It seems likely that time of year, age of leaf, position of basal cut and the level of nutrients in the propagating medium may all be important factors. The results showed, however, that *Streptocarpus* x " Constant Nymph " has the capacity to regenerate either directly, as above, by the inserted leaf itself becoming part of one new plant, or indirectly, as happens in other species, by the leaf producing a number of progeny, which after a few weeks become independent of the parent leaf.

By whichever route regeneration takes place, the inserted leaf produces roots and then continues to grow, the greatest increase in area being near the basal end of the leaf and the smallest near the apex. The

growth of the inserted leaf is an additional reason for supplying nutrients but if a number of progeny rather than only one plant is required from each leaf cutting the exact stage at which nutrients should be given will have to be ascertained. Although growth of the inserted leaf may not be at the expense of the development of the progeny it seems desirable to consider further their respective demands concerning nutrients and to examine the stage at which the progeny should be removed from the leaf cutting.

The quality of the plant from which leaf cuttings are made affects the quality of the progeny subsequently produced. The conditions under which leaves of the source plant are initiated and grow may well be reflected in the progeny which they produce when detached months later. There may thus be variation in the quality of the progeny produced by different source plants and by different leaves from the source plant. In addition, the progeny from any particular leaf cutting may also vary. This may be due to the progeny being initiated over a period of time, or may be the result of differences in their rates of growth due to competition for water and nutrients; certain favourably located progeny growing the fastest. In one experiment the differences noted while the progeny were attached to the leaf cutting were still apparent in the independent plants several months later, both with regard to the size of plant and also to the quantity and size of flowers.

The results obtained from these experiments with *Streptocarpus* emphasise that there are a number of critical stages in propagation by leaf cuttings and that the choice of material and environmental conditions may influence the development and performance of the progeny.

Many of the results with *Streptocarpus* are likely to apply to other species. A fuller understanding of the principles underlying these results will, it is hoped, facilitate the propagation of species now known to regenerate from leaf cuttings and also extend the range to include more species which are of importance in horticulture and plantation cropping.

REFERENCES

(1) HUDSON, J. P. (1955). Propagation of plants by root cuttings. II.—Seasonal fluctuation of capacity to regenerate from roots. *J. hort. Sci.* **30**: 242-251.

(2) HAGEMANN, A. (1932). Untersuchungen an Blattstecklingen. *Gartenbauwiss.* **6**: 69-195.

THE ROLE OF BORON IN PLANT NUTURITION

W. J. Whittington

Earlier experiments [1] [2] emphasized the important relationship that exists between the supply of boron and cell division. There is, however, a lack of knowledge about the changes occurring in the meristem while deficiency is developing. The results of analyses of organs in which deficiency symptoms have long been apparent do not allow the separation of primary from secondary effects. A reduction in the time intervals between analyses during the onset of deficiency reduces, although it does not eliminate, this source of error. The results [3] now to be discussed deal with the changes that occur in the radicle of field bean during the first 96 hours of growth in a nutrient solution lacking boron.

Experimental Methods and Results

Seeds of spring field beans were germinated until their radicles were about 2 cm. long. They were then transferred to germination tanks so that the radicles were growing in a nutrient solution to which either no boron or 1 p.p.m. boron was added. At 12-hourly intervals over the first 96 hours after the treatment began the apical centimetre from each of a number of roots was sectioned into one mm. portions so that results could be obtained for predominantly meristematic cells (sections 1—3 from the root-tip), elongating cells (sections 3—6) and mature cells (sections 6—10). The sections were analysed for cell number, cell volume, respiratory rate, nitrogen, sugar and nucleic acid content.

Deficient roots were found to cease growing after about 30 hours of treatment and the presence of an external supply of sugar in certain experiments did not delay the onset of deficiency symptoms. The deficient roots had enlarged apices and it was found that the third segment actually had fewer cells than a corresponding segment from a normal root. In these roots cell division was found to be absent and it is clear, therefore, that the effect on cell numbers here was due to the enlargement and differentiation of previously formed cells. The idea that division ceases but differentiation continues under boron deficiency was further supported by the finding of xylem elements in sections 1 and 2 where normally only meristematic cells are found.

The results for dry weight and nitrogen content per cell were related to the cell size, while respiration rates were lowered by deficiency. Estimation of sugar content per cell suggested that total sugar was not decreased in the meristem until 48 hours of treatment, by which time cell division had ceased. Certainly at the 96-hour stage the cells of deficient roots, irrespective of their location, contained less sugar than

those of normal roots. Finally, the results obtained for the estimation of ribose- and deoxyribose-nucleic acids per cell showed no difference between deficient and sufficient cells.

Discussion and Conclusion

As deficiency begins in a root the number of cells dividing decreases and each cell will remain in the meristematic region of the root longer than normal. In fact, when division has ceased entirely, all cells retain their positions in the root. In the experiment described above, care has to be taken in the interpretation of the results obtained in comparing cells of different physiological age. Nevertheless, the pattern of deficiency is clear; division ceases but differentiation continues until the apex is occupied by cells which, even on a return to a boronated medium, cannot begin to divide again.

The cessation of mitosis may be a consequence of an effect on cell wall metabolism as a result of which the cell is prevented from becoming organized for division. Alternatively the cells may fail to divide because deficiency has a direct effect on the components of the nucleus of cytoplasm. Sugar, in particular, has been suggested [4] [5] as one component and certainly the experiment has shown that deficient cells are low in sugar. They were not, however, found to be low in sugar at the time the cells ceased division nor did a supply of sugar in the external medium delay deficiency. It is, therefore, believed that in the absence of an active meristem sugar does not move from the seed to the apex, while that translocated earlier is utilized in the differentiation of those cells previously formed.

The evidence obtained that boron deficiency is not concerned with deoxyribose nucleic acid formation was not absolute. Analyses were only made at the 96-hour period of deficiency when DNA content per cell was normal. Yet if it were to be formed too slowly during the onset of deficiency a cell might become differentiated before it had doubled its DNA content as an essential preliminary to division. Estimates of nucleic acid content over the first 48 hours would be valuable.

The lack of evidence for any association between boron and a cytoplasmic component suggests that the element may be concerned with the metabolism of the cell wall. This has already been suggested [6] particularly with regard to the pectin component, and there is a substantial body of indirect evidence that suggests that boron is associated with the synthesis of pectin compounds and is rendered immobile by complexing with them. Pectins, cellulose, and hemicellulose are thought to arise by different pathways from a common precursor, uridinediphosphate-d-

glucose, and boron may be essential for the maintenance of an ordered system. It is possible that in the absence of boron the abnormal cell walls of the meristematic region do not allow the cell to become organized for further division, perhaps as a result of an enhanced elongation rate due to a weakened middle lamella.

The relationship of boron with the cell wall components is the subject of further study as the result of a grant from Borax Consolidated Ltd.

REFERENCES

(1) WHITTINGTON, W. J. (1956). The role of boron in the nutrition of certain legumes. *Rep. Univ. Nottingham Sch. Agric.* 1956: 31-33.

(2) WHITTINGTON, W. J. (1957). The role of boron in plant growth. I.—The effect on g eneral growth, seed production and cytological behaviour. *J. exp. Bot.* **8**: 353-67.

(3) WHITTINGTON, W. J. (1959). The role of boron in plant growth. II.—The effect on growth of the radicle. *J. exp. Bot.* **10**: 93-103.

(4) GAUCH, H. G. and DUGGER, W. M. (1953). The role of boron in the translocation of sucrose. *Plant Physiol.* **28**: 457-466.

(5) SISLER, E. C., DUGGER, W. M. and GAUCH, H. G. (1956). The role of boron in the translocation of organic compounds in plants. *Plant Physiol.* **31**: 11-17.

(6) MARSH, R. P. and SHIVE, J. W. (1941). Boron as a factor in the calcium metabolism of the corn plant. *Soil Sci.* **51**: 141-151.

STUDIES ON COMMON SCAB OF POTATO

B. G. Lewis and T. H. Nicolson

Common scab is one of the most widespread diseases of the potato tuber although potato varieties vary considerably in their susceptibility to it.[1] Causing a blemish which is usually superficial, scab reduces the market value rather than absolute yields. Losses due to this disease are therefore difficult to estimate; however, it has been found that, in certain years, particularly when June and July are dry, up to 4% of the national yield may be classed as "substantially scabbed."[2] Although widely distributed in Britain scab is rarely destructive, but may be severe on light-textured soils, particularly those poor in organic matter. On certain soils, as on the Bunter sands of Nottinghamshire, it may become a limiting factor in potato production.

As with any plant disease, the incidence and expression of potato scab is the result of a complex interaction between host, parasite and environment. The organism inciting the disease is the Actinomycete *Streptomyces scabies*. It is intermediate between the true fungi which form filaments of hyphae and are responsible for many plant diseases and the true bacteria which are generally in the form of single cells and cause some plant diseases. The strains of *S. scabies*, many of which can be obtained from diseased tubers or soil, vary in cultural appearance,

PLATE 1.

Apparatus used so that tubers were accessible for observation and inoculation at any stage of development. The parent tuber was placed in chamber A which was kept moist by Spagnum and lowered into container B filled to the base of A with culture solution. Roots grew down through polythene mesh into the culture solution and stolons and tubers formed in A.

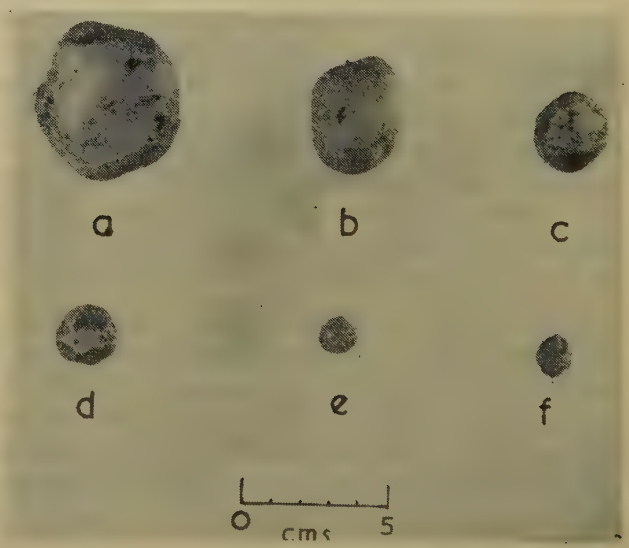


PLATE 2.

Development of scab lesions on tubers grown in damp chambers. Tubers a and b did not grow appreciably after inoculation and show few visible lesions; tubers c-f grew after inoculation and show numerous lesions.

in ability to grow in certain media and in pathogenicity. The variability on the part of the pathogen is a considerable disadvantage when investigating the disease. Various soil factors, chiefly texture, temperature, moisture content and hydrogen ion concentration can considerably influence scab. In addition, the general balance in the soil microbial population can have an important effect. Hence the same, or even greater, difficulties are encountered when studying scab as with any soil-borne disease—we have as Garrett has said "to deal with a triple biological interaction, that between host plant, parasite and general microflora in a varying physico-chemical habitat."

Control of scab by organic manuring has received a great deal of attention. There is some evidence that green manuring reduces scab in certain soils under certain conditions. This is often attributed to the direct effect of changes in the numbers and activities of antagonistic soil micro-organisms. However, organic manuring is not always effective and there is little information on the nature of, or in the changes in, the numbers of the micro-organisms primarily concerned. This system is being examined more fully using known fungal and bacterial antagonists and unknown antagonists on organic matter in sterile compost which has been inoculated with a pathogenic strain of *S. scabies*. Both treatments reduce the amount of scab but it has not been possible to distinguish whether the reduction is primarily due to antagonism or to change in some factor, such as pH or water or oxygen supply, brought about by the treatments. Attempts are being made to devise more direct techniques to explore possible antagonistic effects of soil micro-organisms on *S. scabies*.

The density of visible microflora—actinomycete filaments, fungal hyphae and bacterial cells—has been compared on the tuber surfaces of three varieties, Ulster Chieftain, King Edward and Seneca, which respectively show increasing resistance under normal conditions of cultivation (Table 1). The plants were grown in naturally-infected soil in the field and the tubers examined in June soon after initiation and in August when approaching maturity. The density of total actinomycetes decreased and that of bacteria increased with increasing resistance. It appears, therefore, that the degree of resistance is directly correlated with the numbers of actinomycetes which occur in close proximity to the tuber. This could be a direct effect of the tuber on growth of actinomycetes, i.e. stimulation by the susceptible variety and/or inhibition by the resistant variety. Conversely, the effect may be indirect, since stimulation or inhibition of bacteria would be expected to alter the ecological balance between bacteria and actinomycetes. There was also a much lower density of total micro-organism on older than on younger tubers (Table 1)

TABLE 1

DENSITY OF MICRO-ORGANISMS AND NUMBER OF SCAB LESIONS ON THE SURFACES OF TUBERS OF THREE VARIETIES IN JUNE AND IN AUGUST 1959.

	Ulster Chieftain (susceptible)		King Edward (intermediate)		Seneca (resistant)	
	June	August	June	August	June	August
Total microflora (Actinomycetes, Bacteria and Fungi)	57.5	26.8	27.0	19.3	53.5	22.0
Proportion of total microflora consisting of:						
Actinomycetes	52.9	11.0	23.9	5.9	20.7	2.5
Bacteria	4.6	12.6	2.4	12.2	30.9	16.3
Fungi	0.0	3.2	0.7	1.2	1.9	3.2
Ratio actinomycetes to bacteria	11.5	0.9	9.9	0.5	0.7	0.2
Mean number of lesions per tuber:						
$<$ 3 mm. diameter		5.8		2.5		2.6
$>$ 3 mm. diameter		19.0		1.9		0.4

but the number of actinomycetes decreased and the number of bacteria and fungi increased at the later harvest. These changes in activity may have arisen from a decrease in the soil water content, which was unusually low during the latter part of the experiment; they may, however, be direct responses to changes in the tuber, such as a decrease in the leakage of substances from the tuber or changes in the thickness and composition of the periderm.

The latter explanation would be consistent with the results of experiments we have carried out in the laboratory. An early suggestion of Fellows[3] that growing tubers only could be infected and that resistance apparently developed as the tuber aged has been confirmed. Plants of Ulster Chieftain were grown under controlled conditions and the tubers, isolated in damp chambers, were inoculated with a known density of *S. scabies* spores at specific times (Plate 1). The area of diseased tissue at harvest was directly proportional to the amount of tuber growth at the time of inoculation (Plate 2). The large tubers which did not grow after inoculation and which had a thick periderm (8-9 cells at harvest) showed no lesions. These results do not necessarily indicate that true resistance increases with age; they may simply reflect the fact that the normal scab lesion arises from the passive expansion of localized areas of dead cells as the tuber increases in volume. Using this technique, susceptible and resistant varieties are being compared and information concerning the penetration stage and the expression of disease symptoms is being sought.

REFERENCES

(1) McKEE, R. K. (1958). Assessment of the resistance of potato varieties to common scab. *Europ. Potato J.* **1**: 65-80.

(2) LARGE, E. C. and HONEY, J. K. (1955). Survey of common scab of potatoes in Great Britain, 1952 and 1953. *Plant Path.* **4**: 1-8.

(3) FELLOWS, H. (1926). Relation of growth in the potato tuber to the potato-scab disease. *J. agric. Res.* **32**: 757-781.

CROP VARIETY TESTING

J. C. LLEWELYN
N.I.A.B. Regional Trials Officer

The general trials programme of the National Institute of Agricultural Botany undertaken at the School of Agriculture in 1959 was essentially the same as in the previous year. The acreage of potatoes under trials was doubled to include a foreign variety trial, a yellow flesh trial and a virus-free King Edward trial. Eight foreign varieties were also tested in observation plots. The marrow stem kale trial was discontinued but the thousand head kale trial was extended to include nine additional varieties, again with three dates of cutting. Thirteen varieties of kale were also grown for observation purposes. A silage maize trial was introduced for the first time.

In addition to the main series of trials, plots of Herta barley were again laid down to assist in determining the effect of environment on the development of loose smut. Joint N.A.A.S./N.I.A.B. trials to ascertain the magnitude of the yield losses caused by mildew in cereal chops were also continued and plots of Hesbignon winter wheat, Sun II oats, and Proctor barley, were kept free from mildew by fortnightly sprayings of lime sulphur. Yields were then compared with those of similar plots of the same variety left unsprayed.

A yellow rust trial was continued for the third successive year. This is being carried out in collaboration with the Netherlands Grain Centre as a part of its extensive research on the dissemination and distribution of the physiologic races of the fungus.

Out-centre trials were again grown on the farm of Mr. W. Smith, at Wilson. These consisted of a winter oats, a winter barley and a silage maize trial.

The results of the main 1959 trials are summarised below. These by themselves have a limited application and should be used only as a very tentative guide to varietal performance.

Cereals

Optimum seed-bed conditions ensured a vigorous establishment of winter wheat and the trial over-wintered well. Conditions were less favourable for sowing the out-centre winter cereals, and subsequent emergence was poor.

Spring cereals brairded well and were strongly established before the onset of the extremely dry weather which followed. All the trials looked excellent throughout the season. There was a moderate attack of

mildew with only a slight infection of yellow rust. A considerable amount of loose smut occurred in certain varieties of spring barley. There was little lodging and harvesting conditions were ideal.

In the tables the main control variety is listed first with the yield in cwt. per acre. The yields of other varieties, with the secondary control listed first, are expressed as a percentage of the main control, and are in heavy type where they differ from it significantly (5% level). All yields are at 15% moisture content, and are the means of yields obtained at three levels of nitrogen.

WINTER WHEAT TRIAL

c/a=cwt. per acre

	Hybrid 46	Cappelle Desprez	Elite Lepeuple	Professeur Marchal	Stella	Artois Desprez	Poncheau	Hesbignon	Maitre Pierre	S.80	14431
c/a	40.7	96	100	102	**91**	**91**	95	**85**	98	95	**80**

Slight lodging occurred in Professeur Marchal and Artois Desprez.
Cappelle Desprez was unusually weak-strawed. Hesbignon, Hybrid 46 and Artois Desprez were more susceptible to mildew.
Professeur Marchal and Elite Lepeuple have been placed on the Recommended List.

WINTER OATS TRIAL

S.147	S.172	Powys	E.2295	5370/2/2/41
22.4*	112	**84**	**128**	110

* Control variety failed. Yield estimated from mean comparison with other varieties in all other trials.

SPRING WHEAT TRIAL

Atle	Koga II	Carpo	Jufy II	E.L.S.	Probat	5323
c/a 37.6	**111**	**106**	**105**	102	**112**	**108**

Yellow rust appeared in E.L.S. (International Scale 3), Jufy II (I.Sc.1) and Jufy I (I.Sc.2). Carpo had a trace of loose smut.

SPRING BARLEY TRIAL

Proctor	Maythorpe	Mentor	Union	Vada
c/a 35.7	**91**	104	99	101

Mentor had considerable loose smut; Union and Vada had a moderate infection.

SPRING OATS TRIAL

Sun II	Milford	Angus	Condor	Vigor	V.2661	Max	Phoenix
c/a 29.6	80	87	103	96	77	83	93

Sun II, Milford and Vigor appeared slightly more susceptible to mildew. Symptoms of manganese deficiency appeared in all varieties except Angus. Vigor had a slight attack of crown rust. Condor has been placed on the Recommended List.

Beans

A trial to compare the relative yields of spring and winter beans established well and made excellent growth during spring and early summer. Slight weevil damage occurred and although chocolate spot made an early appearance it remained non-aggressive throughout the season. There was an extensive but otherwise moderate attack of black aphis and half the trial was sprayed with a systemic insecticide as an additional treatment.

Drought eventually caused the crop to mature rather prematurely.

YIELDS AS % OF MEAN YIELD OF WHOLE TRIAL

	Sprayed	Unsprayed	Mean
Gartons S.Q. (winter)	113	108	110
Albyn Tic (spring)	94	85	90
MEAN	104	96	100

Significant difference for bean means=7.4, P=0.05.
Spraying treatments not significant.
Mean yield=19.2 c/a.

Potatoes

Majestic was the control in all trials and its yield of sound tubers at maturity is given in tons per acre. The yield of other varieties or other dates of lifting are expressed as a percentage of control.

The trials emerged fairly well and made vigorous growth despite the lack of rain. There were rather more gaps than usual, due, in many cases to *Corticium solani*. A late frost caused slight damage but the crop quickly recovered. All varieties were ultimately affected by drought, particularly Ulster Grove, Ulster Tarn, 120/18, E62, Seneca and Keswick, and even fairly vigorous varieties such as Majestic, Ulster Glen, and Ulster Torch, lost a considerable amount of lower leaf. A considerable amount of secondary growth occurred in the tubers and dormancy was generally short. The quality of most varieties was impaired to some extent by the incidence of soft rubbery tubers.

The earliness at which the crop finally reached maturity was to be expected. There was no blight.

MAINCROP POTATO TRIAL

t/a=tons per acre

	Majestic	Ulster Beacon	Ulster Glen	Ulster Grove	Ulster Ranger	Ulster Tarn	Ulster Torch	120/18 (P.B.I.)
	t/a							
Total	13.6	102	104	53	93	82	94	81
Over 2"	6.0	166	127	24	115	84	49	69

RATE OF BULKING POTATO TRIAL

Date sprayed off	Majestic		Craigs Royal		Ulster Beacon	
	Total	Over 2"	Total	Over 2"	Total	Over 2"
23rd June	43	0	47	14	45	19
7th July	59	16	70	58	63	51
21st July	84	62	73	46	87	134
4th August	89	84	83	94	108	227
18th August	100	100	81	73	110	210
—	t/a 11.0	t/a 3.7	t/a 8.9	t/a 2.7	t/a 12.1	t/a 7.8

FOREIGN VARIETY TRIAL: Seed ex. N. Ireland

	Majestic	o As	Kayuga	Katahdin	Ontario	Seneca
	t/a					
Total	11.8	84	78	96	117	63
Over 2"	4.0	23	50	165	135	87

FOREIGN VARIETY TRIAL: Seed ex. Cumberland

	Majestic	Canoga	Etoile du Leon	Kennebec	Pungo	Russet Burbank	Saco	Sebago
	t/a							
Total	12.2	120	100	104	85	76	113	104
Over 2"	5.1	137	58	176	75	22	171	184

YELLOW FLESH VARIETY TRIAL

	Majestic	Orion	Panther	E.57(Clarke)	E.62(Clarke)	F.37(Clarke)
	t/a					
Total	12.1	97	78	105	67	82
Over 2"	4.4	109	47	203	31	93

Sugar Beet

Sharpe's Klein E was the control in each trial, and the data are related to it as a percentage.

MAIN SUGAR BEET TRIAL

	Sharpe's Klein E	Eagle Hill Polyploid	Garton's 632	Goldsmith's Dobrovice A	Maribo P	Polyrave
Population/acre	29,500	95	100	97	89	98
Bolters %	0.1	0.4	0.1	0.6	0.3	0.1
Yield of Tops t/a	8.0	88	90	107	87	94
Yield of Washed Roots t/a	15.1	81	95	95	87	97
Sugar %	16.9	18.2	17.6	17.5	18.8	18.0
Yield of Sugar t/a	2.55	87	99	99	96	103

SMALL SCALE SUGAR BEET TRIAL

	Sharpe's Klein E	Battle's Polyploid A	Battle's Polyploid B	Battle's Polyploid C	British Klein E	Garton's LT. 1237	Zwaanesse Poly.
Population/acre	30,700	86	89	90	97	100	95
Bolters %	0.34	0.29	0.38	0.28	0.09	0.08	0.09
Yield of Tops t/a	6.7	87	90	85	104	102	109
Yield of washed roots t/a	13.0	107	109	107	105	99	113
Sugar %	18.0	18.1	18.5	19.2	17.5	18.6	18.4
Yield of Sugar t/a	2.34	107	112	114	103	102	116

Silage Maize

Yields as a percentage of mean yield of the whole trial.

SILAGE MAIZE TRIAL I

Variety	Plant height (inches)	Green Yield	Dry Yield
Caldera 331	60	90	93
Caldera 402	64	97	100
Maisking 5	64	107	104
Pioneer 395	67	106	100
Warwick 277	64	94	94
Wisconsin 270	72	103	110
Wisconsin 355	67	103	98

Mean yield=73.6 c/a of dry material.

SILAGE MAIZE TRIAL II

Variety	Plant height (inches)	Green Yield	Dry Yield
Caldera 331	58	96	94
Caldera 402	61	95	92
Maisking 5	57	113	114
Pioneer 395	65	109	108
Warwick 277	66	105	115
Prior	61	83	76

Mean yield=37.7 c/a of dry material.

FOETAL DEVELOPMENT IN PIGS

J. T. Morgan and F. R. Green

Efficient pig production requires that each sow should rear as many pigs of as high a quality as is possible. Upon occasion a sow will produce 20 or more weaned pigs in a year, but for various reasons the general average is much lower than this. It is axiomatic that if the level of production of the average sow could be raised nearer to that of the best, the resulting economic advantage would be very great.

A number of factors contribute to the production from the average sow falling well below her potential; some of these have been studied over the last few years on the Experimental Farm. Small litters at birth and excessive mortality between birth and weaning are two of the most important factors and both have received attention. Another important factor, the failure to produce litters at the desired six-monthly interval, has not been studied here although it has received considerable attention elsewhere, as, for example, by Pomeroy at Cambridge.[1]

From records kept on the Experimental Farm for some years it has become clear that the later performance of the pigs is dependent on birth weight to a surprising extent. Stillbirth, which in general seems to be responsible for a loss of around 5% of all pigs born, appears to be very largely a result of low birth weight, at least a quarter of the stillborn piglets being abnormally small at birth. Mortality of the piglet in its first few weeks of life tends to be very high; most surveys report a loss of a quarter of all pigs born alive, a figure which is very close to that found on the Experimental Farm. It was found that about a half of this mortality was associated with low birth weights. The major fraction of neonatal mortality falls within the first few days after birth. A study of the growth pattern of these undersized piglets shows them in the later stages of gestation to be not only undersized but with retarded development and with low food reserves in their bodies. This makes them extremely susceptible to the effects of low environmental temperatures, for they cannot adequately maintain their body temperature.

Of the possible factors influencing birth weight, only one has been found to have any significant effect—the size of the litter. For each extra pig in the litter at birth, the average weight declines by between one and two ounces. It might thus be expected that mortality would tend to rise in the larger litter and this in fact is the case. It has been reported before[2] and has been found again at Sutton Bonington that this increase in mortality tends to limit litter size at weaning to 10 pigs

no matter how many are born. Furthermore, this extra mortality appears to be almost entirely a result of the decreased birth weight. If, therefore, the birth weight could be raised it seems that this excessive mortality could be considerably reduced with obvious benefits. However, no method of raising birth weights has so far been discovered; although a few reports of success by feeding methods exist in the literature, these have never been confirmed. In trials on the Experimental Farm, even reducing the food intake of the pregnant sow by a half has failed to have any influence on the birth weight of the litter, and it is known that feeding above the recognised standards tends to have a deleterious effect.

To attempt to unravel some of the factors operating in the growth of the foetus, particularly during the latter part of pregnancy, a number of pregnant sows have been slaughtered over the last few years and their foetal litters examined and dissected. From this a reasonably reliable picture has emerged of the normal pattern of growth and development of the foetal pig and of the variations in it. The growth of the foetus throughout pregnancy from the time when it can first be conveniently measured (at about 28 days) follows a close approximation to a logarithmic or cubic curve, the latter providing a slightly better fit. The piglet, as might be expected, is thus making its maximum growth in the final stages of pregnancy at a time when, as has been shown by Pomeroy[1], the growth of the sow's uterus and of the foetal membranes has almost ceased.

A study of foetal piglets from the 50th day of gestation to full term has shown that the pattern of embryonic development is very similar to that found by McMeekan[3] in the post-natal period. There are, however, certain anomalies which are consistent with there being a considerable restriction in the pig's natural capacity for growth caused by an inadequacy of nutrient supply in utero. This hypothesis fits in very well with the observed fact that embryonic growth outstrips uterine growth and that the smaller foetuses show these effects to a greater extent than the larger. It is known that in larger litters the ratio of foetal weight to uterine weight decreases, which again suggests that the small ratio is associated with the decreased birth weight. It has also been observed by several authors that within litters those foetuses whose embryonic membranes occupy the largest area of the uterus tend to be the largest.

There is thus a considerable amount of evidence that the growth of the foetus during the latter part of pregnancy is considerably restricted by the size of the uterus, and that any attempt to induce greater growth must be done by inducing greater development of the uterus, possibly

earlier in gestation. Unless this can be done, it seems that there is little chance of effecting an improvement in birth weights in an attempt to reduce the excessive neonatal mortality of the pig.

REFERENCES

(1) POMEROY, R. W. (1956). *Reproduction in the sow, with special reference to infertility and neonatal mortality*. Ph.D. Thesis, University of Cambridge.

(2) MENZIES-KITCHIN, A. W. (1937). Fertility, mortality and growth rate in pigs. *J. agric. Sci.* **27**: 611-625.

(3) McMEEKAN, C. P. (1940). Growth and development in the pig, I. *J. agric. Sci.* **30**: 276-343.

FACTORS AFFECTING FERTILITY IN FEMALE SHEEP

D. M. Allen and G. E. Lamming

The rate of propagation of any mammalian species depends on four principal factors :

(a) the age and stage of growth at which puberty is attained,

(b) the ovulation rate and the proportion of the ova which are fertilised and develop successfully,

(c) the duration of pregnancy,

(d) the time interval between parturition and the establishment of a new pregnancy.

These factors affect the reproductive rate in the sheep in three main ways. Firstly, where nutritional conditions are unfavourable ewe lambs may not reach puberty until their second winter of life and, although most British lowland breeds experience a breeding season in their first winter, many farmers do not consider their animals sufficiently well developed to reproduce by this time. Therefore, the ewe may be 18 months old before its first pregnancy is established. Secondly, the number of ova shed at each heat period by most British breeds is usually one to three and this is the main factor limiting prolificacy in the ewe, for foetal atrophy and abortion are not prevalent. Methods designed to improve the ovulation rate are therefore important because of the resultant increase in lambing percentages. Finally, the number of lambs produced in the year is limited by the seasonal rhythm of breeding activity exhibited by the ewe which confines the normal breeding season to the autumn

and winter months. Although the period of gestation is generally shorter than the breeding season, there is an anoestrus associated with lactation which extends into the normal seasonal anoestrus so it is unusual for a fresh pregnancy to be established soon after parturition in the spring.

Studies on the following aspects of these factors have been completed during the period from 1957 to 1959:

(1) The effects of different planes of nutrition during the rearing period in ewe lambs were studied in relation to growth and sexual development.

(2) The relationship between plane of nutrition and reproductive activity in mature ewes was studied with particular reference to the possible mechanisms through which nutrition controls ovulation rate.

(3) The problem of breeding from ewes during their normal non-breeding season was investigated, particularly in lactating ewes.

1. **The effects of nutrition on the growth and sexual development of ewe lambs.**

During the autumns of 1957 and 1958 groups of ewe lambs were reared on two different planes of nutrition, one designed to give a high growth rate while the other was designed to give only a moderate rate of growth. The animals were slaughtered soon after puberty and the development of their reproductive tracts compared. The results showed that an early occurrence of puberty was associated with high body weights and high rates of growth, otherwise puberty was delayed or even inhibited. However, when puberty occurred in lambs fed on a moderate plane it occurred at significantly lower body weights than in the high plane groups. In lambs slaughtered at their first oestrus, the plane of nutrition did not affect their ovulation rate nor the percentage of ova which were fertilised, neither did the plane of nutrition affect the ovulation rate of lambs following an injection of 800 i.u. Pregnant Mares' Serum (P.M.S.).

Further studies are now required to show how the low-plane lambs would react to an established pregnancy. Lambs reared on the higher plane of nutrition had larger reproductive tracts and were in a more advanced stage of body development and it is presumed that they would be better able to withstand the dual strain of pregnancy and continued growth under the relatively unfavourable nutritional conditions normally found during the winter period.

2. **The relationship between nutrition and reproductive activity in the mature ewe.**

In the mature ewe high ovulation rates are associated with a high level of available nutrients in the diet and/or good body condition. On moderate or low levels of nutrition ovarian activity is reduced with the occurrence of "silent heats." High ovulation rates can be induced in ewes in store condition by placing the animals on rapidly improved feed for a short period before breeding. This practice is known as "nutritional flushing" and is widely used to ensure high lambing percentages. In spite of this wide use in practice the mechanisms through which nutrition controls ovarian activity are not fully understood.

Preliminary experiments demonstrated that when ewes in store condition were flushed on improved feed there was a marked increase in ovulation rate after one month. There was no further increase in ovulation rate if the flushing period was extended to two or three months, neither was there any evidence that flushing led to ovulation rates higher than those found in ewes maintained for long periods in fat condition (Table 1). If ewes in fat condition were fed sub-maintenance diets so that they lost weight there was no decline in ovulation rate while the animals had good body reserves but as the period of sub-maintenance feeding was extended and the ewes became thin, there was a gradual fall in ovulation rate (Table 1).

TABLE 1

THE EFFECT OF NUTRITIONAL FLUSHING AND SUB-MAINTENANCE DIETS ON LIVE-WEIGHT AND OVULATION RATE IN MATURE EWES

Treatment		Live-weight change as % of initial live-weight	Ovulation rate Mean+S.E.
Store Ewes		—	1.50±0.22
Flushed	4 weeks	+16.4	2.17±0.16
	8 weeks	+27.5	2.17±0.16
	12 weeks	+30.7	2.00±0.00
Fat ewes		—	2.33±1.06
Sub-maintenance diets	4 weeks	−11.4	2.00±0.82
	8 weeks	−16.1	1.50±0.91
	12 weeks	−21.6	1.40±0.77

In a later experiment ewes in store condition were flushed for shorter periods. It was shown that after periods of 7—8 days, one oestrous cycle (16 days) and two oestrous cycles (32 days), there was a linear increase in ovulation rate from 1.33 in ewes in store condition to 2.17 in ewes flushed for two oestrous cycles. On the other hand, ewes maintained for long periods on sub-maintenance diets lost 27.7% of their initial live-weight and when slaughtered in thin condition exhibited only single

ovulations these being associated in some animals with "silent heats." When similar ewes given the same nutritional treatments were injected with 600 i.u. of P.M.S. there was no evidence that nutrition had any effect on the sensitivity of the ovaries to this form of gonadotrophin, and those on sub-maintenance diets averaged 2.40 ova following such treatment.

This failure to record any differences in the response of the ovaries to P.M.S. regardless of the previous plane of nutrition, suggested that nutrition did not exert its effect on ovulation rate by any direct action on the ovaries. Bioassay studies were, therefore, carried out on anterior pituitary material from ewes on the different treatments. The chick assay was used to provide a semi-quantitative estimate of the potency of total gonadotrophin, and the results suggested that low ovulation rates were associated with high levels of gonadotrophin in the pituitary gland at slaughter two to five days post-oestrus. From this it was concluded that the plane of nutrition affects ovarian activity by regulating the release of gonadotrophin from the pituitary gland and that possibly some psychic stimulus is involved in this response.

3. **The induction of breeding activity in ewes during anoestrus.**

The seasonal rhythm of breeding activity in sheep is primarily under photoperiodic control and for most British breeds the breeding season is evenly spaced on either side of the shortest day.[1] Breeding activity can be induced outside the normal breeding season by artificially manipulating the diurnal light-dark ratio. Oestrus can also be induced during normal anoestrus by giving a series of progesterone injections followed by a single injection of P.M.S. Although non-lactating animals conceive at normal rates when oestrus is induced in this way, conception rates have been low in ewes lactating strongly when treated.[2]

In field trials during 1957, 1958 and 1959, maiden ewes not previously mated during their first winter were injected with progesterone and P.M.S. at approximately 12 months of age. The most successful form of treatment proved to be a series of three intra-muscular injections of 50 mg. progesterone (in oil) at three-day intervals, the last progesterone injection being followed after 48 hours by a subcutaneous injection of 750 i.u. of P.M.S. Using this treatment the oestrous percentage varied from 60% to 92% and conception rates were high (Table 2). This appeared to provide a reliable method of obtaining a crop of lambs from maiden ewes not bred from during their first winter, and is certainly one which could now be widely used by farmers to provide young lambs for sale in January and February.

TABLE 2

THE RESULTS OF FIELD TRIALS IN THE PRODUCTION OF LAMBS FROM MAIDEN EWES DURING THE NON-BREEDING SEASON

Year	Treatment	No. of ewes treated	No. of ewes which mated	No. of ewes which lambed	No. of lambs produced
1957	6 x 12.5 mg. progesterone +750 i.u. P.M.S.	30	8	5	7
1958	3 x 50 mg. progesterone +850 i.u. P.M.S.	30	18	17	24
1959	3 x 50 mg. progesterone +850 i.u. P.M.S.	26	24	22	24

A field trial with lactating ewes in the early summer of 1957 using various combinations of progesterone and P.M.S. produced very disappointing results and of 100 ewes treated only 11 exhibited oestrus and only four of these lambed. It was obvious that lactation inhibited the response already achieved with maiden ewes and that further experiments were required.

Forty lactating ewes were used in an experiment to compare reproductive phenomena when they were slaughtered :—

(i) after no treatment during anoestrus (10 ewes);

(ii) after breeding activity had been induced by injections of progesterone and P.M.S. using the injection therapy described above (20 ewes);

(iii) after breeding activity had been induced, in response to the animal's endogenous endocrine secretions, by imposing a short-day treatment.

(The lighting regime consisted of four hours light, two hours dark, four hours light and 14 hours dark, in each day and provided a ratio of two parts of dark to one part of light) (10 ewes).

The injections of progesterone and P.M.S. induced ovulation in 19 of the 20 treated ewes and oestrus accompanied ovulation in 12 ewes. The failure of the remaining eight ewes which did not show signs of oestrus did not appear to be related to an inadequate stimulation of the ovaries by gonadotrophin with lowered oestrogen production, for oestrus failed to occur in some ewes with up to five ovulations. Apparently there is some unexplained difference between a period of normal breeding activity and that produced by these injections which affects the build-up of the sensitive state where both oestrus and ovulation occur together.

The recovery of ova from ewes which mated after injections of progesterone and P.M.S. showed that there was a complete failure of fertilization and that this could not be attributed to poor semen quality in the rams used.

The short-day treatment induced ovulation in all 10 treated ewes and oestrus was observed in nine ewes. The response was slow, oestrus occurring 92 to 115 (mean 101) days after the commencement of treatment. The oestrus was preceded by a " silent heat " as at the approach of the normal breeding season. Of the ova recovered from the oviducts, 41.2% were cleaving, a successful result when compared to the complete failure above.

This failure of fertilization in ewes which mate after injections of progesterone and P.M.S. is difficult to explain. It did not appear to be related to the form of treatment *per se*, for ewes lactating after an autumn lambing showed high conception rates when they mated seven to eight weeks after parturition. Perhaps the improved fertilization rate of ewes subjected to the short-day treatment provides an indication of the factors involved. In these ewes oestrus was preceded by a " silent heat " and the cyclic events associated with it may have some function in preparing the reproductive tract for the fertilization of ova and, possibly, the subsequent development of embryos.

It would appear that the hormone treatment used can be applied successfully to the production of an extra crop of lambs from maiden ewes during the non-breeding season. However, before the problem of breeding from lactating ewes outside the normal breeding season is solved, further studies are required to determine the forms of treatment which will give a high oestrous response and to investigate the factors involved in the failure of conception noted in this experiment. Most farmers who breed sheep could take immediate advantage of the increase in ovulation rate which results from the correct use of nutritional flushing for this provides the most practical way of ensuring a high ovulation rate. Only when this technique has been exploited to a maximum should farmers consider using the more complicated methods of increasing fertility.

REFERENCES

(1) HAFEZ, E. S. E. (1952). Studies on the breeding season and reproduction of the ewe. I.—The breeding season in different environments. II.—The breeding season in one locality. *J. agric. Sci.* **42**: 189-231.

(2) GORDON, I. (1958). The use of progesterone and serum gonadtrophin (P.M.S.) in the control of fertility in sheep. II.—Studies in the extra-seasonal production of lambs. *J. agric. Sci.* **50**: 152-197.

THE RESPONSE TO FERTILISER APPLICATION OF SOME EAST MIDLAND FATTENING PASTURES

R. Bennett Jones and K. E. Hocknell

Much of the grass in the East Midlands is permanent pasture. In the counties of Leicestershire and Northamptonshire, over the four years 1955 to 1958, 75% of the grassland acreage was permanent pasture and this covered 50% of the total acreage of crops and grass (excluding rough grazings). In the four years prior to the Second World War the corresponding figures were 96% and 81%.

The traditionally famous Midland fattening pastures are situated largely within these two counties, the most renowned being concentrated in the Market Harborough area. Many of these pastures have not been ploughed in living memory, but the best will fatten two bullocks per acre in a grazing season. Generally, fairly heavy, mature store cattle are purchased in the Spring and the majority of these are sold fat during the Summer and Autumn. Few cattle are over-wintered as most farms lack suitable buildings, and the relatively small acreages of arable crops which are grown do not leave large quantities of by-products. The pastures are not grazed by cattle during the Winter since most of the land is heavy in nature and poaching reduces the productivity of the sward in the following Spring and Summer. Sheep flocks are often carried on farms in the Midland grazing area, and these are used to " clean-up " the fattening pastures during the Autumn and Winter. Another feature of the management of this grassland is the low rate of fertiliser usage, often limited to occasional dressings of lime and basic slag. The rates[1] of fertiliser application to permanent pasture in the Midlands are, however, much lower than the average rates of application to this type of grass in grassland areas and far lower than the rates of application to permanent pasture in dairying areas, e.g. the Fylde district of Lancashire. The percentage of the total area to which fertiliser is applied is also much lower in the Midlands than in the dairying areas.

There is little data available from controlled experiments to show what responses are likely from fertiliser application to permanent pasture, and the data that are available often refers to dry matter yields rather than to yields of animal products. Although data relating to fertiliser applications and liveweight gains of the grazing animal are available for leys these results may not be applicable to permanent pasture because of the lower inherent productivity of the species and strains making up the sward of this type of grassland. The responses measured in controlled

experimental work may also differ from those obtained on commercial farms. Thus, recommendations of fertiliser dressings to permanent pastures are made somewhat speculative.

The answer to the question " Will it pay to apply fertilisers to permanent grass being used for beef production ? " cannot be given without three relevant facts :

(1) The cost of fertiliser applied,

(2) The price of beef,

(3) The quantity of extra beef produced.

The first two facts can be readily determined for any given period, but the quantity of beef (or extra liveweight gain) resulting from a given application of fertiliser can only be determined by experiment. In 1958 and 1959, therefore, a simple experiment was conducted on a number of commercial farms in the Market Harborough area.

In 1958 twelve farmers who grazed beef cattle on permanent pasture were selected to co-operate in the investigation. In the following year the investigation was expanded and twenty farmers co-operated, including nine of those who had taken part in 1958.

Two fields (or on some farms one divided field) were set aside for the experiment on each farm. As far as possible the fields were matched with regard to size, previous manurial treatment, uniformity, and " quality " as a " fattening field " as assessed by the farmer. One field (Field A) was fertilised and one field (Field B) was left not fertilised on each farm. Managerial skill (especially in assessing stocking rates) was assumed to be equal on both fields, any differences in the management and output of the two experimental fields being due only to the result of the fertiliser application.

The average sizes of the experimental fields on the twelve co-operating farms in 1958 were 10.3 acres and 11.3 acres for the fertilised and not fertilised fields respectively. On the twenty farms co-operating in the following year the average size of the fertilised fields was 10.7 acres and that of the not fertilised fields was 11.3 acres.

In 1958 five cwt. per acre of a 5 : $12\frac{1}{2}$: $12\frac{1}{2}$ compound fertiliser were applied to Field A in the Spring of that year. In the second year of the investigation three cwt. per acre of an 8 : 12 : 8 compound fertiliser were applied to Field A. On farms which co-operated in the investigation for both years the fertiliser was applied to the same field in each year.

The co-operating farmers were encouraged to apply the fertiliser as soon as possible in the Spring. In Table 1 are presented the " average date " of fertiliser application, the " average date " of the commencement of the grazing season and the length of the grazing season, for each year of the investigation. In each year and on each farm the grazing began on the same day on both fields.

TABLE 1

AVERAGE DATES OF FERTILISER APPLICATION, COMMENCEMENT OF GRAZING SEASON, AND LENGTH OF GRAZING SEASON (DAYS)

Year	Date of fertiliser application	Date of commencement of grazing season	Length of grazing season (days)	
			Field A	Field B
1958	18th March	1st May	163	163
1959	15th March	19th April	151	142

The cattle grazing the experimental fields were as evenly matched as possible with regard to weight, condition, sex, method of wintering, or if purchased, place of origin. The co-operating farmers were encouraged to manage the cattle on the experimental fields as they would under normal farming conditions. The cattle placed on the fields were weighed on a portable weigh-bridge at the commencement of the grazing season, and were subsequently weighed at approximately six-weekly intervals and at the end of the grazing season. If a farmer wished to move any cattle on to or off the fields between the regular weighings these cattle were weighed at the time of moving.

It is realised that the time of weighing will affect the weight of the cattle due to varying " gut-fill." Tayler[2] has shown that the liveweight of bullocks can vary from 20-36 lb. in a day due to varying " gut-fill." However, since in this study differences of liveweight gain rather than the absolute liveweight gain were sought, and since the cattle from both fields were weighed under the same conditions and at the same time, no corrections to the recorded weighings were made.

Soil tests with respect to lime, (Ca O), phosphate, (P_2O_5) and potash, (K_2O), were carried out on the experimental fields, and Grassland Husbandry Officers of the National Agricultural Advisory Service made botanical assessments on some of the experimental fields during August, 1959. From the results of the soil tests carried out on the experimental fields of the farms co-operating in 1958 seven of the farms had lime requirements of over 25 cwt. per acre on both fields. Those farmers co-operating in the second year of the investigation corrected these

deficiencies during the Winter of 1958-59. Only two farms showed a phosphate analysis of " low " and only one farm had soil with a " low " potash content. Botanical assessments were carried out on the experimental fields of eleven of the co-operating farms. The dominant sward species on all of these farms was Agrostis, and the clover content of the swards was generally low. On each of the farms there were virtually no botanical differences between the swards of the fertilised and not-fertilised fields.

Results

In the first year of the study some 600 cattle grazed the experimental fields, and in 1959 the fields were grazed by 690 cattle. The average weights of the cattle placed on to the experimental fields and the average stocking rates of the experimental fields are shown in Table 2.

TABLE 2

AVERAGE LIVEWEIGHTS OF CATTLE PLACED ON TO THE EXPERIMENTAL FIELDS AND THE AVERAGE STOCKING RATES OF THE FIELDS

Year	Average liveweights of cattle placed on fields (lb.)		Average stocking rates (beasts per acre)	
	Field A	Field B	Field A	Field B
1958	918	900	1.12	1.02
1959	932	922	0.88	0.77

The average liveweight gains per acre and the difference in liveweight gains per acre for each year are presented in Table 3.

TABLE 3

AVERAGE LIVEWEIGHT GAINS PER ACRE AND AVERAGE DIFFERENCE IN LIVEWEIGHT GAINS BETWEEN FERTILISED AND NOT FERTILISED FIELDS

Year	Average Liveweight Gains (lb. per acre)		Differences (A – B)	
	Field A	Field B		
1958	367.0	330.0	37.0	±18.2
1959	307.1	269.7	37.4	±11.0

From the periodic weighings of the cattle on the experimental fields it has been possible to calculate the approximate liveweight gains per acre for each month of the grazing season. The results of these calculations show that in 1959, the dry year, the live-weight gain during the first three months grazing was higher than in 1958, as was the percentage of the eventual difference between the fertilised and not fertilised fields. After May, the live-weight gains in 1959 were lower for each month than in 1958.

Table 4 shows a summary of the financial results of the investigation. It should be noted that no account has been taken of the cost of spreading the fertiliser, of any extra capital costs involved, or of any residual affects of the fertiliser application.

The average response to fertiliser application in lb. live-weight gain per acre was insufficient to cover the cost of the fertiliser applied in both 1958 and 1959. However, in 1958 three farms did show a response to fertiliser application which was above the 76 lb. per acre of extra live-weight gain required to cover the cost of the fertiliser. In 1959, eight farms had responses greater than the 44 lb. required to cover the cost of the fertiliser applied in that year.

TABLE 4

SUMMARY OF FINANCIAL RESULTS PER ACRE

Item	1958	1959
Cost of fertiliser (£. s. d.)	4. 15. 0.	2. 15. 0.
Extra liveweight gain (lb.)	37.0	37.4
Value of extra gain at £7 per live cwt. (£. s. d.)	2. 6. 3.	2. 8. 0.
Margin of extra returns over extra costs (£ s. d.)	(–) 2. 8. 9.	(–) 8. 3.
Extra gain required to cover cost of fertiliser (lb.)*	76	44
Plant nutrients (lb.) applied in fertiliser:		
Nitrogen	25	24
Phosphate	62½	36
Potash	62½	24

* Assuming price of fat cattle per live cwt. is equal to the price of store cattle per live cwt.

Discussion

In considering the results outlined above it must be remembered that 1958 was one of the wettest summers on record and 1959 one of the driest.

Experimental work at the School of Agriculture[3] in 1957 demonstrated that, when cattle were grazed at a fixed rate of stocking, no extra liveweight gain was derived from fertilised as opposed to unfertilised plots. Ivins, therefore, concluded that no benefit could be derived from increased production of grass unless the existing animal potential was increased by adopting a higher rate of stocking. In other words, the capacity of an individual animal to gain weight is limited and higher liveweight gains per acre can only be achieved by putting on extra animals to eat the extra grass which may be available.

Figure 1 shows that, in both 1958 and 1959 the liveweight gain per acre increased with rate of stocking. It can be deduced from the regression equation (calculated from observations of both fertilised and not fertilised fields in both years) that 25 lb. of the extra liveweight gain may be attributed to the extra stock per acre carried on the fertilised fields.

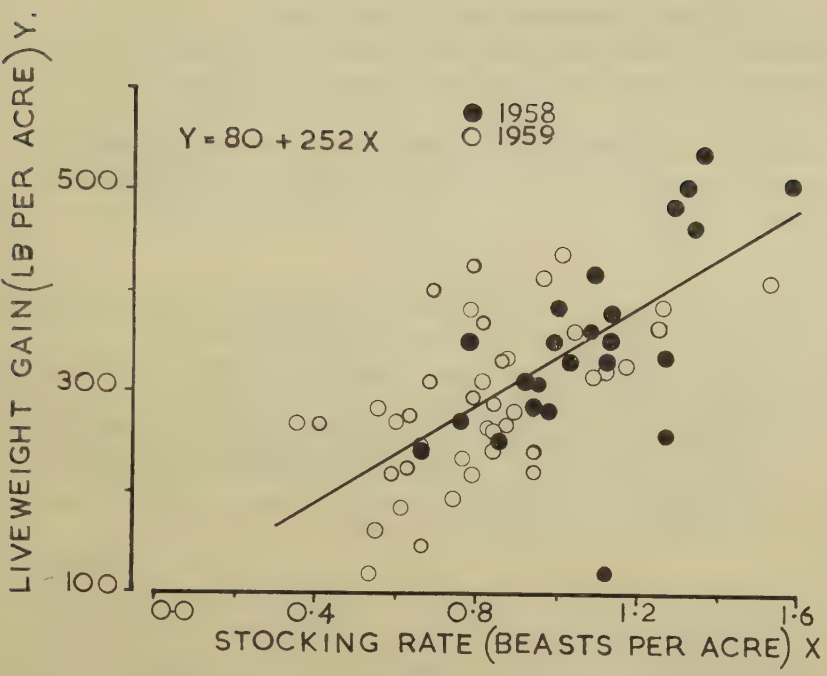


Fig. 1.

In the wet year of 1958 the grazing season was the same length on both the fertilised and the unfertilised fields. In 1959, when it was exceptionally dry, the fertilised field yielded, on average, nine more days of grazing than the unfertilised field. This may explain the liveweight gain not " accounted " for by the difference in stocking rates in that year.

The fertilisers used in these experiments contained a relatively high proportion of phosphate and potash. In 1958, the extra liveweight gain obtained was sufficient only to pay for about one half the cost of the fertiliser applications. In 1959, approximately the same quantity of nitrogen, but only about 60% as much phosphate and 40% as much potash were applied. The extra liveweight gain obtained per acre was very slightly more than in 1958 and almost equal in value to the reduced cost of the fertilisers used.

Experimental work[4] has shown that heavy applications of nitrogen can increase the yield of dry matter from a sward despite a reduction in the clover content. It is possible, therefore, that an economic return may be obtained from appropriate applications of nitrogenous fertilisers to permanent grassland used for beef production. Further experimental

work is required to test the validity of this hypothesis. It should be noted, however, that the botanical character of these swards, which are predominantly Agrostis, may limit their response to fertiliser applications.

Thanks are due to Messrs. Fisons, Limited, who financed this investigation, and to the farmers and their staffs, for their co-operation and help at weighings.

REFERENCES

(1) *Survey of fertiliser practice,* 1957, Pts. I and II, (1958). National Agricultural Advisory Service and Rothamstead Experimental Station.

(2) TAYLER, J. C. (1954). Technique of weighing the grazing animal. *Proc. Brit. Soc. Anim. Prod.* 1954. 3-16.

(3) IVINS, J. D., DILNOT, JEAN and DAVISON, J. (1958). The interpretation of data of grassland evaluation in relation to varying potential outputs of grassland and livestock. *J. Brit. Grassl. Soc.* **13**: 23-28.

(4) WILLIAMS, R. and LLOYD, J. R. (1952). An experiment on the nitrogenous manuring of grass.*N.A.A.S. Quart. Rev.* **5** (No. 18): 271-276.

THE WEATHER IN 1959

T. Webster

General

The year was warm, dry and sunny. This was so particularly from May to October, giving the finest summer and autumn for many years, though crops could have done with considerably more rain. Summer rainfall was the lowest ever recorded in England and Wales; it was drier than average locally, especially in May and June, than in most other districts. Combined with the consistently good weather were fairly large deviations in most parameters from the average. Fogs and serious frosts were confined almost entirely to the early part of the year, and appreciable snow lay only in January.

Rainfall

Eight months had rainfall below average, February and September being particularly dry, each having only one day on which measurable rain fell. Between May and September England and Wales generally had 7.5 inches of rain, the lowest ever recorded for the period; whilst locally there were only 2.76 inches or 28% of normal. April had the

greatest positive deviation of rainfall from the average, but November and December had higher actual rainfalls; that of December having been exceeded only once in the previous 14 years. The pattern of rain days was very similar to that of rainfall, the only slight discrepancy being in March in which the rainfall was 10% lower than average and the number of rain days 16% greater than average. There has been no drier year locally for at least the past 14 years.

Sunshine

Only three months had sunshine below average, none during the summer when a deficit means a much lower absolute amount of sunshine. The monthly figures were above average in January and December and consistently so from April to October; the important May to August total being 26% above normal.

Temperature

Despite having the greatest number of hours of sunshine above average of all months January was the only month in which the mean screen temperature was below average. The remainder of the year, particularly October, was very warm, except for November, which was little above normal. The soil temperature pattern was similar except that the increase at 2 feet compared with 4 and 8 inches was less in summer, and the high air temperature in October had only a slight effect in the soil.

Crops

As in the previous two seasons, winter crops were saved from the worst frosts by snow cover, though slight damage was done by less severe frosts later. Early spring sowing conditions were excellent, and locally some corn was sown in February. With the high temperatures and April rainfall, emergence was rapid and full. Potatoes and timely-sown beet also established well, with only slight frost damage to the former, but very dry conditions from May onwards produced some very patchy crops of later-sown beet, mangels and kale.

Early summer growth was excellent, but drought effects began to show by the end of June, particularly in root crops. The continuing dry weather caused much wilting in potatoes, which flowered and senesced early and produced crops with much second growth. The effect on beet, beans and kale was accentuated by an extremely heavy aphid attack, which was only partially controlled by several insecticidal sprayings.

There was a heavy incidence of beet virus yellows, and a moderate attack of chocolate spot helped to ripen the beans prematurely. Mildew in the cereals was moderate, and only traces of yellow rust were observed. No potato blight was seen but common scab was widespread, some varieties being severely affected.

Cereals were harvested almost without a check, generally in excellent condition, though there was some shrivelled grain. Yields, except for oats, were good. Potatoes yielded surprisingly well, but grade and quality were very poor, and dormancy had already been broken in most varieties.

Sugar beet made a surprising recovery with some rain in October, and harvesting conditions and yields were good. Sugar content was exceptionally high. Kale crops were very poor, and forage became so scarce that silage was being fed in early July.

There were some delays in winter sowings where land was too hard to plough, but many crops were sown in good time and in the very mild conditions grew excellently.

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	YEAR
A. Rainfall (inches)	2.44	0.10	1.30	2.14	0.30	0.76	1.00	0.69	0.01	1.78	2.23	3.08	15.83
Rainfall as % of average 1916-1950	112	6	92	127	16	52	42	31	1	84	101	160	69
No. of times rainfall exceeded in previous 14 years	2	14	8	2	14	13	10	12	14	7	4	1	14
No. of rain days	15	1	15	14	5	11	10	7	1	11	19	24	133
Rain days as % average 1946-1959	103	8	116	126	40	79	83	51	8	92	132	153	84
B. Total sunshine (hours)	78.8	54.0	80.5	148.1	206.7	246.6	235.8	201.8	166.7	143.8	37.8	39.6	1640.2
Sunshine as % of average 1921-1950	192	90	75	107	118	130	131	125	136	150	70	124	121
No. of times sunshine exceeded in previous 14 years	0	9	10	6	2	1	1	1	2	0	14	6	0
C. Mean daily radiation ($mw\text{-}hr.\ cm^{-2}\ day^{-1}$)	68	91	180	318	419	499	469	357	288	169	63	40	247
D. Temperature (°F)													
(1) Mean screen maximum	39.6	44.5	51.3	56.7	63.7	69.0	73.9	73.8	69.6	63.8	49.3	47.3	58.5
(2) Mean screen minimum	27.7	33.5	37.7	41.1	43.0	49.4	52.6	53.3	46.3	44.8	37.3	37.3	42.0
(3) Average of (1) and (2)	33.7	39.0	44.5	48.9	53.3	59.2	63.3	63.5	57.9	54.3	43.3	42.3	50.3
(4) Deviation from average 1921-1950	−4.7	+0.1	+2.3	+2.2	+1.3	+1.6	+1.7	+3.0	+1.6	+4.7	+0.3	+2.9	+1.4
(5) Soil temperature at 4″	34.1	36.9	41.3	46.6	54.4	61.6	65.1	63.2	56.8	49.9	42.3	40.2	49.4
(6) Deviation from average 1946-1959	−3.0	+0.1	+2.0	+1.5	+2.2	+3.3	+3.4	+3.0	+1.0	+0.8	−0.8	+0.8	+1.2
(7) Soil temperature at 8″	36.1	38.0	42.4	46.7	53.6	60.3	64.0	62.9	58.3	52.0	44.3	41.8	50.0
(8) Deviation from average 1946-1959	−2.1	+0.2	+2.2	+1.5	+1.9	+3.0	+3.0	+2.8	+1.8	+1.6	−0.1	+1.1	+1.4
(9) Soil temperature at 2′	40.2	39.5	43.7	47.8	52.4	57.8	61.6	61.7	59.3	55.1	48.4	45.2	51.1
(10) Deviation from average 1946-1959	−0.2	+0.1	+2.2	+1.5	+0.7	+0.6	+0.5	+0.6	+0.9	+2.1	+1.1	+2.2	+1.0

UNIVERSITY OF NOTTINGHAM
SCHOOL OF AGRICULTURE

PUBLICATIONS
1959

AGRICULTURAL BOTANY

F. L. MILTHORPE

Transpiration from crop plants. *Field Crop Abstr.* **12**: 2-9, (1959).

Studies of the expansion of the leaf surface. I.—The influence of temperature. *J. exp. Bot.* **10**: 233-49. (1959).

F. L. MILTHORPE (with D. ASPINALL)

An analysis of competition between barley and white persicaria. I.—The effects of growth. *Ann. appl. Biol.* **47**: 156-172. (1959).

T. H. NICOLSON

Mycorrhiza in the Gramineae. I.—Vesicular-arbuscular endophytes, with special reference to the external phase. *Trans. Brit. mycol Soc.* **42**: 421-448. (1959).

W. J. WHITTINGTON

The role of boron in plant growth. II—The effect on growth of the radicle. *J. exp. Bot.* **10**: 93-103. (1959).

AGRICULTURAL CHEMISTRY

D. LEWIS (with E. F. Annison)

The thyroid peripheral metabolism in sheep during pregnancy. *J. agric. Sci.* **52**: 79-86. (1959).

D. LEWIS (with E. F. Annison and D. B. Lindsay)

The metabolic changes which occur in sheep transferred to lush spring grass. I.—Changes in blood and rumen contents. *J. agric. Sci.* **53**: 34-41. (1959).

The metabolic changes which occur in sheep transferred to lush spring grass. II.—Changes in the acid-base balance of the whole animal. *J. agric. Sci.* **53**: 42-45. (1959).

D. V. CRAWFORD

The availability of plant nutrients. *Nature, Lond.* **184**: 159-160. (1959).

AGRICULTURAL MICROBIOLOGY

M. WOODBINE

Microbial fat: Micro-organisms as potential fat producers. *Progr. Industr. Microbiol.* **1**: 179-245. (1959).

M. WOODBINE (with P. Wix)

Mycological synthesis of fat from whey. I.—Preliminary studies with stationary cultures. *J. appl. Bact.* **22**: 14-22. (1959).

AGRICULTURAL ZOOLOGY

E. A. C. HAGLEY

Pyrethum—a note on its horticultural application. *Pyrethum Post.* **5**: 14-23. (1959).

P. W. MURPHY

Soil faunal investigations. *Rep. For. Res., Lond.,* 1957-58: 106-7. (1959).

DAIRYING

R. SCOTT

Contributions to *Cheesmaking. Bull. Minist. Agric. Lond.* 43. H.M.S.O. (1959).

Control of cheesemaking by physical measurements. *Dairy Engrg.* **76**: 280-285, 295. (1959).

The Stilton cheese industry. *J. Soc. Dairy Tech.* **12**: 209-215. (1959).

EUNICE W. WHITT

A surface film method of evaluating quaternary ammonium compounds. *J. appl. Bact.* **21**: 272-277. (1958).

AGRICULTURE

J. D. IVINS (Ed.)

The measurement of grassland productivity. Proc. Univ. Nottingham 6th Easter Sch. Agric. Sci. Butterworths Scientific Publications, London. (1959).

J. D. IVINS

The interpretation of animal production data in grassland evaluation. *Proc. Univ. Nottingham 6th Easter Sch. Agric. Sci.*: 148-55 (1959).

Milk production from grassland. *J. Soc. Dairy Tech.* **12**: 204-9. (1959).

G. E. LAMMING

Recent developments in the use of growth stimulants in farm animals. *J.R. agric. Soc.* **119**: 41-51. (1958).

A. W. J. BROOME, G. E. LAMMING and M. WOODBINE

Studies on the relationship between ovarian hormones and uterine infection. I.—The effect of ovarian hormones on the bactericidal activity of blood plasma. *J. Endocrin.* **18**: 209-219. (1959).

A. W. J. BROOME and G. E. LAMMING

Studies on the relationship between ovarian hormones and uterine infection. II.—The effect of ovarian hormones on the antibacterial activity of the uterine environment. *J. Endocrin.* **18**: 220-228. (1959).

A. W. J. BROOME and G. E. LAMMING

Studies on the relationship between ovarian hormones and uterine infection. III.—The role of the antibody system in uterine defence. *J. Endocrin.* **18**: 229-235. (1959).

J. T. MORGAN, F. R. GREEN, R. A. COSTAIN (with E. F. Williams)

The effect of hexoestrol implantation on growth, efficiency of food utilization and carcass quality in pigs. *J. agric. Sci.* **51**: 370-376. (1958).

Growth, economy of feed utilization and carcass quality in pigs in relation to dietary protein level and antibiotic administration. *J. agric. Sci.* **52**: 170-176. (1959).

F. R. GREEN and J. T. MORGAN

The anatomy of a double pig. *Vet. Rec.* **70**: 704-706. (1958).

J. T. MORGAN

Feeding the milking sow and litter. *Pig Farming,* **7** (11): 36, 42. (1959).

The rearing of dairy heifers. *Ayrshire Cattle Soc. J.* **31**: 186-191. (1959).

D. G. A. GUTTRIDGE and J. T. MORGAN

Methionine supplementation of broiler diets at varying protein levels. *World's Poult. Sci. J.* **15**: 380-386. (1959).

MRS. N. McDERMOTT (with G. Samuel)

Potato varieties in the United Kingdom—Some statistics prepared for Sub-Committee, Plant Breeders' Rights, Ministry of Agriculture, Fisheries and Food.

J. DAVISON

Experiences in the measurement of herbage consumption by livestock. *Proc. Univ. Nottingham 6th Easter Sch. Agric. Sci.*: 80-8. (1959).

The digestibility of herbage by dairy cows. *Proc. Univ. Nottingham 6th Easter Sch. Agric. Sci.*: 171-80. (1959).

HORTICULTURE

J. P. HUDSON

Weather, crops and man. Inaugural lecture. University of Nottingham. (1959).

Use of controlled environments in experimental work. *Advanc. Sci.,* **15**: 425-(1959).

Horticulture *in* Britannica Book of the Year for 1958. *Encyclopoedia Britannica.* (1959).

Factors affecting yield of tomatoes. *Guernsey Growers' Assoc. Rev.* **23**: 13-21. (1959).

Plants and the weather, Masters Memorial Lecture to the Royal Horticultural Society, Pts. 1-2. *J. Roy. Hort. Soc.* **84**: 443-459, 509-524. (1959).

Effects of environment on *Rubus idaeus* L. I.—Morphology and development of the raspberry plant. *J. Hort. Sci.* **34**: 163-169. (1959).

W. HEYDECKER

Über die Tröpfchen-Bewässerung. *Technik im Gartenbau.* (1959).

Watching for openings in the battle of weeds. (Report on the British Ecological Society Conference on the Biology of Weeds). *Comm. Gr.* 1959 (3302): 945-6.

Feeding garden plants, a progress report on the science of fertiliser use in 75th Anniversary Edition, *Amateur Gardening.* (1959).

Reflections on the latest world seed testing convention. *Comm. Gr.* 1959 (3322): 271-2.

J. DANCER

Synergistic effect of zinc and gibberellin. *Nature, Lond.* **183**: 901-2. (1959).

I. H. WILLIAMS

Effects of environment on *Rubus idaeus* L. II.—Field observations on the variety Malling Promise. *J. Hort. Sci.* **34**: 170-175. (1959).

Effects of environment on *Rubus idaeus* L. III.—Growth and dormancy of young shoots. *J. Hort. Sci.* **34**: 210-218. (1959).

Effects of environment on *Rubus idaeus L.* IV.—Flower initiation and development of the inflorescence. *J. Hort. Sci.* **34**: 219-228. (1959).

AGRICULTURAL ECONOMICS

R. BENNETT JONES (with G. B. BISSET and E. DAWSON)

The economics of potato storage. Joint Publication of the Universities of Leeds, Nottingham and Reading, 1959.

R. BENNETT JONES

Farming in the East Midlands: financial results 1958-59. (University of Nottingham. F.R. No. 141). (1959).

Farm Management Notes No. 21. Autumn, 1959.

LECTURES AND PAPERS—1959

M. N. BORAH (with F. L. Milthorpe):

'The Influence of Temperature on Tuber Formation in the Potato', to the Society of Experimental Biology at Swansea.

P. M. BREMNER:

'Recent Advances in Agriculture', to Ashby Young Farmers' Club.

R. A. COSTAIN:

'Breeds of Dairy Cows', to West Bridgford Young Farmers' Club.

'Pig Nutrition', to Ashby Young Farmers' Club.

J. DAVISON:

'Experiences in the Measurement of Herbage Consumption by Livestock', to the University of Nottingham 6th Easter School in Agricultural Science at Sutton Bonington.

'The Digestibility of Herbage by Dairy Cows', to the University of Nottingham 6th Easter School in Agricultural Science at Sutton Bonington.

WINIFRED M. DULLFORCE:

'Chrysanthemums: Practices that Influence Time of Flowering', to National Agricultural Advisory Service County Durham-Yorkshire N.R. Horticultural Conference at Stockton-on-Tees.

'Factors Affecting the Flowering of Chrysanthemums', to The Vaughan Horticultural Society, Leicester.

MIRIAM M. EDWARDS:

'The Relation between Oxygen Supply and Dormancy in Seeds of *Sinapsis arvensis*', to the Society of Experimental Biology at Copenhagen.

H. G. EVANS:

'Planning a Farm for Greater Profits', a Course of Three Lectures to Long Bennington Farmers' Group.

'Small Farmers' Scheme', to Ashover Farmers' Club.

'Selection of Enterprises on the Small Farm', to Warwickshire County Federation of Young Farmers' Clubs', at Morton Morrell.

'The Place of the Small Farm in the National Agricultural Economy', to Warwickshire County Federation of Young Farmers' Clubs at Morton Morrell.

'Why are Some Farms More Profitable than Others?' to Retford and District Young Farmers' Club.

F. R. GREEN:

'British Agriculture', to Lutterworth Young Farmers' Club.

'Rearing and Feeding for Beef', to Sleaford Branch of the National Farmers' Union.

R. D. HARKESS:

'The Principles of Silage Making and Feeding with Special Reference to the Self-feeding of Dairy Cows', to Uttoxeter Branch of the National Farmers' Union.

W. HEYDECKER:

'Can We Measure Seedling Vigour?' to 12th International Seed Testing Convention at Oslo.

J. P. HUDSON:

'Plants and the Weather', Masters Memorial Lecture to Royal Horticultural Society at London.

'Factors Affecting the Yield of Tomatoes', to Guernsey Growers' Association.

'Food and People', to Nottingham Rotary Club.

'Factors Affecting Tomato Production', to the Leicestershire Commercial Horticultural Discussion Society at Leicester.

J. D. IVINS:

'Grass Leys', to Midland Counties Agricultural Valuers' Association at Birmingham.

'Experiments in Potato Production', to Lichfield Branch of the National Farmers' Union.

'Research in Progress at Sutton Bonington', to Sleaford Branch of the National Farmers' Union.

'The Intepretation of Animal Production Data in Grassland Evaluation', to the University of Nottingham 6th Easter School in Agricultural Science at Sutton Bonington.

'Milk Production from Grassland', to Society of Dairy Technology at Sutton Bonington.

'Developments in the Intensification and Utilisation of Grassland', to the Fertiliser Manufacturers' Association Conference at Harrogate.

'Production from Grassland', to Brackley and District Farming Club.

'Aspects of Grassland Utilisation', to Felton Farmers' Discussion Society.

'A Fresh Approach to Quality in Dried Grass', to Association of Green Crop Driers at Eastbourne.

'The Nutritive Value of Forage', to Haymakers' Group at Sutton Bonington.

R. BENNETT JONES:

'The Scope for Co-operation', to Welsh Agricultural Organisation Society Ltd. at Aberystwyth.

'Agricultural Credit', to Rutland Agricultural Executive Committee at Oakham.

G. E. LAMMING:

'The Use of Hormones in Animal Production', to National Agricultural Advisory Service and National Farmers' Union Meeting at Boston.

'The Hazards of Keeping Livestock Intensively', to Meetings arranged by the National Agricultural Advisory Service at Wragby and Brigg.

Programme 'Fertility in Farm Animals' on B.B.C. Television series 'Farming'.

'Parasite Control and the Use of Hormones in Sheep Production', to Kesteven Farm Institute at Caythorpe.

'The Use of Hormones in Meat Production', to the British Cattle Breeders' Club at Chester.

'The Use of Hormones in Animal Production', to the University College of North Wales Agricultural Society at Bangor.

'Use of Hormones in Sheep Production', to the Welsh Sheep Conference at Newtown, Montgomeryshire.

'The Influence of Ovarian Hormones on Uterine Infection', to 3rd World Congress on Fertility and Sterility at Amsterdam.

'Recent Developments and Future Possibilities on the Use of Hormones in Livestock Production', to Leicester Corn and Agricultural Merchants.

F. L. MILTHORPE:

'Water Relations of Plants', to Nottingham Biological Society.

'Plant Physiology in the Service of Agriculture', Public Lecture at the University of Reading.

'Plant Factors Involved in Transpiration', to U.N.E.S.C.O. Symposium on Water Relations of Plants in Arid and Semi-Arid Zones at Madrid.

NORA McDERMOTT:

'Potato Growing with Special Reference to Varieties', to Electrical Development Association Meeting at Bedford.

'Potato Growing with Special Reference to Varieties', to the Agricultural Group of the Society of Chemical Industry at London.

'Potato Growing with Special Reference to Varieties', to the East Riding Institute of Agriculture and Pocklington Branch of the National Farmers' Union.

'Potato Growing with Special Reference to Varieties', to the County Federation of Discussion Societies at Bishop Burton.

'Potato Growing with Special Reference to Varieties', to National Agricultural Advisory Service Potato Conference at Spalding.

'Early Potatoes', to National Agricultural Advisory Service and Potato Marketing Board Conference at Southport.

'Potato Varieties and Their Management', to British Sugar Corporation Staff Conference at Harrogate.

'Potato Growing with Special Reference to Varieties', to Selby and District Agricultural Club.

'Potato Growing with Special Reference to Varieties', to National Agricultural Advisory Service Conference at Boston.

'Potato Growing with Special Reference to Varieties', to Ashby-de-la-Zouch Branch of the National Farmers' Union.

'Potato Growing with Special Reference to Varieties', to Moulton Farm Institute.

J. T. MORGAN:

'Pig Nutrition', to Harper Adams Agricultural College Discussion Society.

'Progress in Animal Production', to Leicestershire and Rutland Farm Institute at Brooksby.

'The Nutrition of Ewes and Dairy Cows', to National Agricultural Advisory Service and National Farmers' Union Conference at Writtle.

'Use of Stockfeed Potatoes', to National Association of Seed Potato Merchants' Conference at Sutton Bonington.

'Methionine Supplementation of Broiler Diets at Varying Protein Levels', to World's Poultry Science Association at London. (with D. G. A. Guttridge).

'Recent Developments in Animal Nutrition', to National Agricultural Advisory Service Conference at Sutton Bonington.

'Scientific Aspects of Pig Husbandry', to Electrical Development Association Meeting at Bedford.

P. NEWTON (with F. L. Milthorpe):

'The Influence of Light on Cell Division in Leaves of Cucumber', to the Society of Experimental Biology at Swansea.

K. RASMUSSEN:

'Meeting Competition in the Years Ahead', to Daventry Farmers' Discussion Group.

'Feeding the World's Population', to Beeston Rotary Club.

'Short Term and Long Term Economic Prospects for Farming in this Country', to Farnsfield and District Farmers' Discussion Group.

R. SCOTT:

'Dairying in Denmark', to Society of Dairy Technology at Derby.

'The Stilton Cheese Industry', to Society of Dairy Technology at Sutton Bonington.

'Heat Exchange', to Society of Dairy Technology at Birmingham.

'Physics in Cheesemaking', to Conference of the Physics Department, National Institute for Research in Dairying, at Reading.

A. SEAMAN:

'The Early Development of Dairy Microbiology', to the Society of Applied Bacteriologists at London.

A. SEAMAN and M. WOODBINE:

'Microbiological aspects of the Genus *Microbacterium*', to the Society of Applied Bacteriologists at London (with Patricia A. Turbutt).

W. S. SENIOR:

'Planning Small Farms for Greater Profit', a Course of Four Lectures to Ingoldsby Farmers' Study Group.

'Background to the Small Farmers' Scheme', to Queniborough Farmers' Discussion Group.

'Agricultural Economics and Farm Management', to Osbournby Farmers' Discussion Group.

'The Economics of Beef Production', to East Midlands Province Agricultural Land Service Staff at Nottingham.

'Problems of the Small Farm', to Farnsfield and District Farmers' Discussion Group.

'The Small Farmers' Scheme', to Loughborough Branch of the National Farmers' Union.

'Management of the Larger Farm', to Metheringham Farmers' Discussion Group.

'The Use of Mechanisation Efficiency Standards', to Annual Conference of National Agricultural Advisory Service Machinery Advisory Officers at Sutton Boningon.

'The Small Farmers' Scheme', to Ashby-de-la-Zouch and District Branch of the National Farmers' Union.

'Economics of Leys on Mainly Arable Farms', to Lincolnshire National Agricultural Advisory Service Staff at Lincoln.

'The Use of Accounts in Farm Management', a Course of Two Lectures to Grantham Farmers' Study Group.

'Farm Economics', to Edenham Farmers' Discussion Group.

'Current Trends on Smallholdings', a Course of Two Lectures to Eagle and District Farmers' Study Group.

'Agricultural Policy', to Grantham Farmers' Study Group.

W. R. SHORTHOSE:

'The Use of Hormones in Fattening Stock', to Conference on Hormones and Meat at East Riding Institute of Agriculture.

T. W. D. THEOPHILUS:

'The Use of Farm Accounts for Farm Management', a Course of Four Lectures to Manton Farmers' Discussion Group.

'The Economics of Farm Management', to Leicestershire National Agricultural Advisory Service at Redmile.

'Management of the Small Farm', to Buxton Branch of the National Farmers' Union.

'The Economics of Farm Management', to Hinckley Branch of the National Farmers' Union.

'Analysis of Farm Accounts', to Brooksby Old Students' Association at Brooksby.

'Farm Management and Organisation', to Redmile Farmers' Discussion Group.

'Management of the Small Farm,' to National Agricultural Advisory Service Farmers' Group Meeting at Hilton.

'Economics of Farm Management', to Ashby-de-la-Zouch Branch of the National Farmers' Union.

'Economics of Farm Mechanisation', to Queniborough Farmers' Discussion Group.

'Economics of Farm Management', to Lutterworth Branch of the National Farmers' Union.

N. WHITE:

'Recent Developments in Beef Production', to Moulton Farm Institute.

'The Use of Hormones in Animal Production', to Farnsfield Farmers' Discussion Society.

'The Use of Hormones in Livestock Production', to Shuttleworth College of Agriculture at Biggleswade.

R. O. WOOD:

'Farm Accounts', to Widmerpool and District Young Farmers' Club.

'Farm Book-keeping', to Belper and District Young Farmers' Club.

M. WOODBINE:

'Careers, Opportunities or Prospects in Agriculture, Horticulture and Agricultural Science', to York Schools Careers Conference at York.

'Microbes by the Million', the initial lecture of a 'Health Problems Under Intensive Management' course organised by the East Riding Institute of Agriculture at Bishop Burton.

TITLES OF THESES ADMITTED FOR HIGHER DEGREES IN THE FACULTY OF AGRICULTURE AND HORTICULTURE 1959

AGRICULTURAL SCIENCES

BORAH, M. N.

The effect of light intensity, length of day and temperature on growth and tuber formation in the potato. **Ph.D.**

FAHMY, T. K.

The carbohydrate, fat and protein relations in food yeasts, with special reference to the genus *Hansenula*. **Ph.D.**

HUGHES, D. L.

Studies on bovine mastitis—with particular reference to the seasonal and annual incidence of the bacterial species involved. **Ph.D.**

LAKIN, A. L.

The estimation of fibrous carbohydrates in herbage. **M.Sc.**

SMITH, K. N.

Cultural and inhibitory studies on the genus *Rhizobium*. **M.Sc.**

SMITH, L. B.

Population dynamics of the rust-red grain beetle, *Cryptolestes ferrugineus* (Steph.). **Ph.D.**

AGRICULTURE

ALLEN, D. M.

Some factors affecting fertility in female sheep. **Ph.D.**

DAVISON, J.

The animal/pasture complex in relation to the evaluation of grassland. **Ph.D.**

GREEN, F. R.

The study of foetal growth and development in the pig. **Ph.D.**

HORTICULTURE

MARSTON, M. E.

The behaviour of isolated leaves of Streptocarpus. **Ph.D.**

PUBLICATIONS FOR SALE

LIMITED STOCKS OF THE FOLLOWING PUBLICATIONS ARE AVAILABLE FROM THE DEPARTMENT OF AGRICULTURAL ECONOMICS AT THE PRICES SHOWN

Agricultural Labour in England and Wales: Part I. 1900-1920. (1949). 4s. 0d. MEJER, E.

Agricultural Labour in England and Wales: Part II. Farm Workers' Earnings. (1951). 5s. 0d. MEJER, E.

Sand Land Farming. (1949). 1s. 6d. MEJER, E.

Farming in the Lincolnshire Limestone Areas, 1936-1947. (1950). 2s. 6d. SMITH, J. H. and RICHARDSON, PRUDENCE P.

Labour in relation to Economic Efficiency on Dairy Farms. (1952). 5s. 0d. NALSON, JOHN S.

The Pattern of Farming in the East Midlands. (1954). 6s. 0d. JONES, R. BENNETT.

Economics of Grain Drying and Storage. (F.R. No. 131). (1955). 2s. 0d. THEOPHILUS, T. W. D.

Tulip and Narcissus Forcing in 1954-55 *and Previous Seasons.* (F.R. No. 135). (1956). 2s. 0d. INGERSENT, K. A.

The Costs of Rearing Single Suckled Calves. (F.R. No. 137). (1956). 2s. 0d. BROWN, A.

Farming Types and Financial Results 1956-57. (F.R. No. 139). (1957). 2s. 0d. HUNT, R. W. T.

A Study of Potato Pre-packing Costs. (1958). 5s. 0d. WARLEY, THORALD and BARON, DONNAN.

Farming in the East Midlands: Financial Results 1957-58. (F.R. No. 140). (1958). 4s. 0d. JONES, R. BENNETT.

The Economics of Potato Storage. (1959). 5s. 0d. JONES, R. BENNETT, BISSET, G. B. and DAWSON, E.

Farming in the East Midlands: Financial Results 1958-59. (F.R. No. 141). (1959). 4s. 0d. JONES, R. BENNETT.

Farm Management Notes, Nos. 9, 11, 13, 14, 17, 18, 19, 20 and 21. 1s. 6d. each.

STOCKS OF THE FOLLOWING PUBLICATIONS ARE AVAILABLE FROM THE DEPARTMENT OF HORTICULTURE AT THE PRICES SHOWN

Water-regimes in Irrigation Research. (Reprinted from the Report of the 14th International Horticultural Congress, Netherlands, 1957). 1s. 0d. HUDSON, J. P., SALTER, P. J., and MAJMUDAR, A. M.

Plants and their Water Supplies. (Reprinted from Endeavour, 16, 84-9, 1957). 1s. 0d. HUDSON, J. P.

Weather, Crops and Man. Inaugural Lecture, 1958. 2s. 0d. HUDSON, J. P.

Effects of Environment on Rubus idaeus L. (Reprints of a series of five papers published in the Journal of Horticultural Science, 1959). 2s. 6d. HUDSON, J. P. and WILLIAMS, I. H.

THE FOLLOWING PUBLICATION MAY BE OBTAINED FROM THE SECRETARY TO THE SCHOOL OF AGRICULTURE

Key for the Identification of Potato Varieties in the Field. (1957). 2s. 6d. McDERMOTT, NORA.

THE PROCEEDINGS OF THE SECOND, THIRD, FOURTH, FIFTH AND SIXTH UNIVERSITY OF NOTTINGHAM EASTER SCHOOLS IN AGRICULTURAL SCIENCE MAY BE OBTAINED FROM ANY BOOKSELLER, THE DETAILS ARE AS FOLLOWS:

Soil Zoology. Proceedings of the Second Easter School in Agricultural Science, University of Nottingham 1955. Editor: D. Keith McE. Kevan. Publishers: Butterworths Scientific Publications, London, 1955. Price 55s. 0d.

The Growth of Leaves. Proceedings of the Third Easter School in Agricultural Science, University of Nottingham 1956. Editor: F. L. Milthorpe. Publishers: Butterworths Scientific Publications, London, 1956. Price 40s. 0d.

Control of the Plant Environment. Proceedings of the Fourth Easter School in Agricultural Science, University of Nottingham 1957. Editor: J. P. Hudson. Publishers: Butterworths Scientific Publications, London, 1957. Price 42s. 0d.

Nutrition of the Legumes. Proceedings of the University of Nottingham Fifth Easter School in Agricultural Science 1958. Editor: E. G. Hallsworth. Publishers: Butterworths Scientific Publications, London, 1958. Price 55s. 0d.

The Measurement of Grassland Productivity. Proceedings of the Sixth Easter School in Agricultural Science, University of Nottingham 1959. Editor: J. D. Ivins. Publishers: Butterworths Scientific Publications, London, 1959. Price 35s. 0d.

ECHO PRESS LTD., LOUGHBOROUGH